UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Chancellor Boulevard Redesign - Team 20

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University of British Columbia

CIVL 445

Themes: Transportation, Community, Land

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1.0 Executive Summary

J3MRK's recommended roadway redesign extending from west of Acadia Road to west of Drummond Drive, seeks to provide a welcoming access to the Pacific Spirit Regional Park as well as an efficient route for passage through the University Endowment Lands from the City of Vancouver. The major aspects of the design may be summarized as follows:

- Multi-use underpass for pedestrians and cyclists at the intersection of Hamber and Chancellor Boulevard designed to provide a convenient and safe passageway across the boulevard for the community.
- A road diet rendering Chancellor Boulevard as a two-lane roadway with bicycle lanes and multi-use pathways on either side.
- Traffic operations at Hamber Road and Acadia Road based on 2041 vehicular volume forecasts are anticipated to be satisfactory with no changes to the existing signal.
- Following the removal of combined sewer overflows (CSOs), a new tunnel drainage system will be incorporated to augment and optimize the drainage capacity of the existing system against a 1 in 100 year storm event.
- The provision of space for the purposes of stationing public bikeshare amenities, car-sharing vehicles, electric vehicle charging, as well as family parking spaces to ensure that parks are accessible to the greater public.
- The anticipated total project cost is $5.21 million.
- The project has a design life of 25 years for lighting components, 50 years for roadwork and 100 years for all other project infrastructure.

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2.0 Introduction

Chancellor Boulevard is one of the roads connecting the University Endowment Lands to the City of Vancouver.

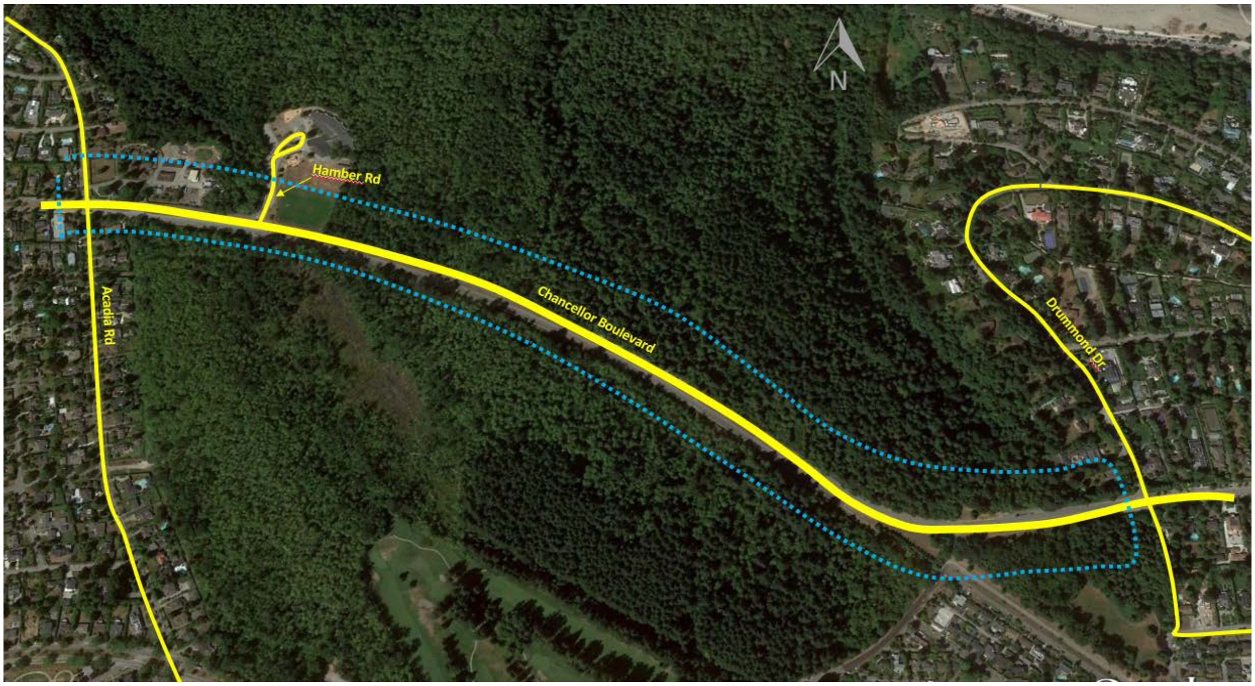

Figure 1 - Project Extents

Currently, there are several points of improvement for the corridor. From west of Acadia Road to the west of Drummond Drive, the current environment could be shifted from a motor vehicle dominated environment to one that encourages active transportation. While the corridor is currently serviced by the 44 and the 84 bus, walking and cycling transport modes should be supported as well. The existing poorly maintained multi-use pathway was constructed to support these modes, but have fallen into disrepair. For pedestrian crossings, there is only an intersection at Hamber to service the nearby University Hill Elementary School and another motor vehicle prioritized crossing for the park trails. Additionally, the 85th percentile of the speed is above the posted speed limits.

J3MRK has been selected by the University of British Columbia's Campus and Community Planning (C+CP) office to complete a design for the Chancellor Boulevard Redesign Project. The design we propose aims to install traffic calming measures to reduce vehicle speeds, an underpass at Hamber to more safely let school and bus users to cross the corridor safely, and generally update the corridor to more modern standards such as streetlights. To this point, J3MRK has completed site survey and investigations, stakeholder consultations, and permit applications. The overall goal of this report is to accurately convey design plans and the due diligence behind proposed construction methods.

Using the following software, the design team has checked to ensure the safety and security for all those who use Chancellor Boulevard:

Design Software	Design Component
AutoCAD	Drafting
SAP	Structural
SkyCiv	Structural
Synchro 6	Traffic Analysis

Table 1 - Design Software

2.1 Summary of Contributions

Tasks	Primary	Secondary	QA/QC
Executive Summary	Jeremy Tse	Janz Arqueza	Maria Albitar
Introduction	Janz Arqueza	Jeremy Tse	James Lee
Design Specifications	Maria Albitar	Klassen Mok	James Lee
Transportation Planning	Maria Albitar	Klassen Mok	Jeremy Tse
Geotechnical Analysis	Maria Albitar	James Lee	Ruddy Ndina
Geometric Design on Road	Klassen Mok	Janz Arqueza	Jeremy Tse
Underpass	James Lee	Jeremy Tse	Maria Albitar
Lighting	Maria Albitar	N/A	Janz Arqueza
Utilities	Ruddy Ndina	Klassen Mok	Jeremy Tse
Computer Modelling	Synchro: Maria Sketchup: James AutoCAD: Janz / Klassen	N/A	Synchro: Klassen SketchUp: Ruddy AutoCAD: Maria
Construction Planning	Ruddy Ndina	James Lee	Maria Albitar
Project Schedule	Ruddy Ndina	Klassen Mok	James Lee
Maintenance Plan	Jeremy Tse	Maria Albitar	Ruddy Rdina
Cost Estimate	James Lee	Klassen Mok	Jeremy Tse

Table 2 - Summary of Contributions

3.0 Design Specifications/Criteria

3.1 Regulations

Given the heavy impact of this project as well as its geographical location, the redesign of Chancellor Boulevard will require adherence to various sets of standards and regulations relating to each aspect of the design, and can be summarized as follows:

Section	Subsection	Regulation	Reference
Drainage	Storm Design Flows	TAC standards (1999) Chapter 1000 Hydraulics Fisheries & Oceans Canada Stormwater Guidelines Surrey MMCD Surrey Design Criteria 2016	• Surrey Design Criteria 2016 Sections 5.3 & 5.4 • MMCD 2009 DWG SSD - D.8, SSD - D.12, S-8, S-11, S-12
	Stormwater Management	Metro Vancouver Best Management Practices Guide for Stormwater 1999 Stormwater Source Control Design Guidelines 2012	• SSCDG Sections 5, 7, & 8 • Surrey Design Criteria Sections 5.3 & 5.4
Geotechnical Engineering	Bearing Capacity	Bridge Standards and Procedures Manual (2016) for concrete structures	
Transportation Engineering	Roadway	Road Design	• TAC 1.2 • See Note 1.
		Road Geometry	• TAC 1.2, 2.1, 2.3
		Signage	• BC Manual of Standard Traffic Signs & Pavement Markings Sections 1-6
		Pavement Markings	• BC Manual of Standard Traffic Signs & Pavement Markings Section 7
	Bicycle Facility	Bicycle Facility Design	• TAC 3.4
		Bicycle Facility Geometry	• See Note 2. • TAC 2.1 and 3.4 • MassDOT Separated Bike Lane Planning & Design Guide (3.3.3 and 4.3.2)
	Pedestrian Facility	Pedestrian Facility Sidewalk and Grading	• See Note 3.

Structural Engineering	Design Loads (CSA S6.14)	Load Factors and Load Combinations	Section 3.5 Table 3.1
		Live Loads	Section 3.8
		Dead Loads	Section 3.6
		Other Loads	Section 3
	One-Way Slab Design (CSA A23.3)	Reinforcement Ratio	Cl.10.5.2
		Minimum Reinforcement Area	• Cl.10.5.1.1 • Cl.10.5.1.2
		Strength Requirement	Cl.8.1.3
		Cracking Control	Cl.10.6.1
		Shrinkage and Temperature Reinforcement	• Cl.7.8.1 • Cl.7.8.3
	Basement Wall Design (CSA A23.3)	Wall Thickness	Cl.14.3.6.1
		Tension Reinforcement	Equation 5.4
		Shear Reinforcement	• Cl.11.2.8.1 • Cl.11.3.6.3b • Cl.14.1.8.4 • Cl.14.1.8.3
	Footing Design (CSA A23.3)	Concrete Shear Strength	Cl.11.3.3 Cl.13.3.6.1 Cl.11.3.4
		Flexural Reinforcement	Cl.15.4.2 Cl.15.4.3
		Design Checks Minimum Reinforcement area Reinforcement Ratio Bar Spacing	• Cl.7.8.1 • Cl.10.5.2 • Cl.7.4.1.2 • Cl.13.10.4
Accessible Structures	Ramps	Dimensions and Slope	NBCC 2010 Division B Section 9.8

Environmental	Fisheries and In-Stream Works	Regulations under Fisheries and Oceans Canada given that Pacific Spirit Regional Park contains salmon-bearing streams British Columbia Ministry of Environment's standards and best practices for in-stream works	• Fisheries Act Section 6 • BC Ministry of Environment Standards and Best Practices for in-stream works Sections 1-10
	Roadwork	Road Sustainability Criteria	INVEST ver. 1.2 System Planning for Regions (SPR) Project Development (PD) Operations and Maintenance (OM)
Lighting	Roadway Lighting	Luminaire type: cobra glass head Luminosity calculations	BC Electrical Engineering Guidelines Section 304.3.9
	Materials	Ministry's recognized products list with 150 W HPS	BC Electrical Engineering Guidelines Section 308.3.2
	Underpass Lighting	Pedestrian and cyclist amenities	BC Electrical Engineering Guidelines Section 304.2.3
Construction	Construction Planning	Project Management Body of Knowledge (PMBOK) 2000 Edition	• Section 3.3.1 • Section 6.3.1 • Section 12.1

Table 3 - Design Specifications

Note 1: For AutoTURN simulations of turning movements, a 5 km/h turning speed shall be used.

Note 2: City of Vancouver Wiki states: "When designing on-street separated bike lanes please consider that in order to use the standard street sweeper a minimum 2.5m width is required."

Note 3: The recommended minimum transverse gradient for bikeways and sidewalk is 1%. Where surface drainage is provided by adequate longitudinal and lateral slope of the ground away from the bikeway and sidewalk, the minimum grade may be reduced to 0.5%.

3.2 Sustainability

Sustainability is a core value in the team's design philosophy. This project has applied eco-friendly and sustainable design practices for the entire design process. In alignment with UBC's sustainability goals, innovative initiatives have been incorporated for the design. This includes the implementation of strategies to promote sustainable modes of transportation over automotive vehicles. Design considerations include prioritized bicycle lanes to promote the safety of cyclists, an underpass for pedestrians and cyclists to safely cross Chancellor Boulevard and a maintained pathway for both pedestrian and cyclist use for travel along the corridor. In order to assess the sustainability of the road, INVEST will be the road rating system used. Despite Greenroads having 3rd party certification available and a well-established rating system, projects that are not rated under the Greenroads road rating system cannot be compared (Abdul, 2012). INVEST can also be used in the planning, operation, and maintenance stages as well with refined criteria for small scale projects such as the redesign of Chancellor Boulevard.

3.3 Societal

Although the project is expected to produce beneficial outcomes to those who use the area, there may be negative impacts on those in and surrounding the area. For example, a road closure would affect people's access to different places. As such, the design team has identified the following major stakeholders who may be impacted through phases of the project, which can be found in Appendix A.

For this project, a stakeholder engagement plan was implemented. This multifaceted plan aimed to both inform and to obtain stakeholders' opinions in a structured and timely way, running from November 2017 to April 2018. The stakeholder engagement plan follows strategies from UBC's Campus + Community Planning engagement principles (University of British Columbia Campus + Community Planning, n.d.). These strategies include stakeholder engagement in the form of informing, consulting, joint problem solving, collaborating and partnering. Firstly, stakeholders were identified and reached out to. Secondly, public notice such as fliers and town halls were given in order to more accurately gauge opinions during the design phase. Feedback was sought from the conceptual stage in order to reduce the amount of design change iterations. Finally, formalized consultations were held with major stakeholders as part of the permitting process and design progress was relayed on a timely basis. A copy of the town hall flyer used for the stakeholder engagement plan can be found in Appendix A.

3.4 Design Life

Due to different standards' requirements and practical maintenance schedule afterwards, different components of the project have different design lives. These are:

Design Aspect	Design Life
Underpass Design Life	100 years
Roadwork	50 years
Lighting	25 years

Table 4 - Design Life Components

4.0 Technical Analysis

A variety of software has been used in determining the specifications of our final results as detailed in the subsequent sections.

4.1 Transportation Planning

Existing 2017 volumes were obtained from a site visit on October 10, 2017; where flows along Chancellor Boulevard in addition to turning movements through the intersections at Acadia Road and Hamber Road were also noted. The existing traffic counts are summarized as shown in the figure below. No pedestrian crossings were observed at Acadia Rd., while 30 pedestrian crossings were observed crossing Chancellor Boulevard at Hamber, arriving in groups of 3 or more.

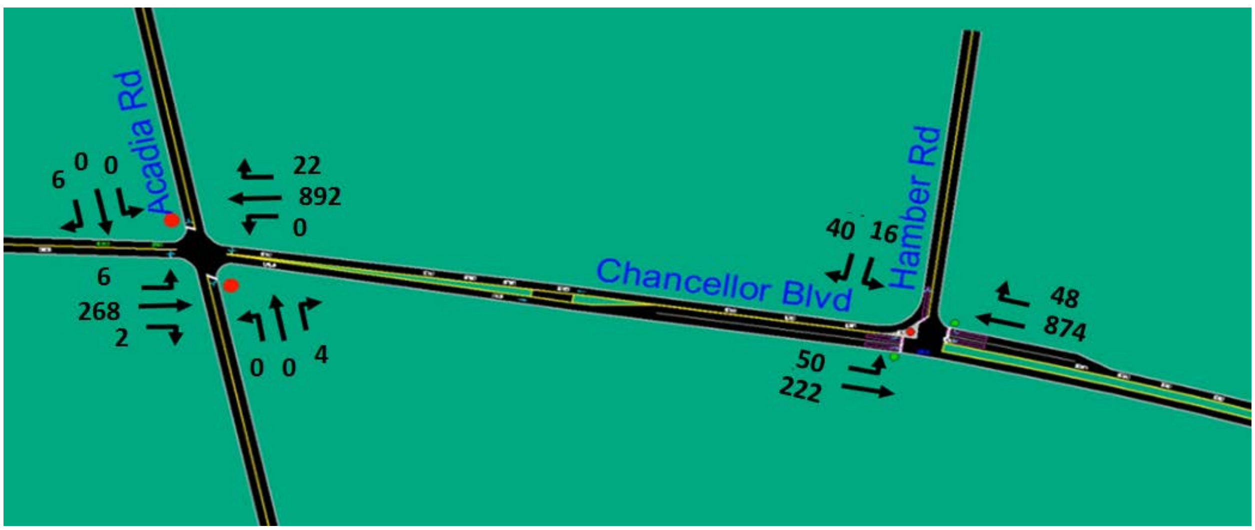

Figure 2 - Present Traffic Counts

4.1.1. Growth Rate

In order to forecast the horizon year of 2041, data on student enrollment growth in addition to on-campus housing supply was analyzed. It was determined that student enrollment growth had been relatively steady at 2.5%; meanwhile, on-campus housing supply is anticipated to grow more rapidly as part of the UBC Vancouver Campus Plan.

The current modal split for non-singly occupied vehicles entering and exiting UBC is 63%. Given the Mayor's 10-Year Vision in addition to TransLink's plans of extending the Millennium Line to Arbutus as part of phase 1 of the MLBE and to UBC as part of phase 2, it is likely that vehicular trip patterns will not significantly increase from 2017 levels. Additionally, pedestrian and cyclist provisions as part of the corridor redesign are anticipated to encourage the utilization of these modes. Nevertheless, a conservative growth rate of 1.25% (half the student enrollment growth rate) was used to observe potential adverse effects on the system, with volumes summarized in the figure below.

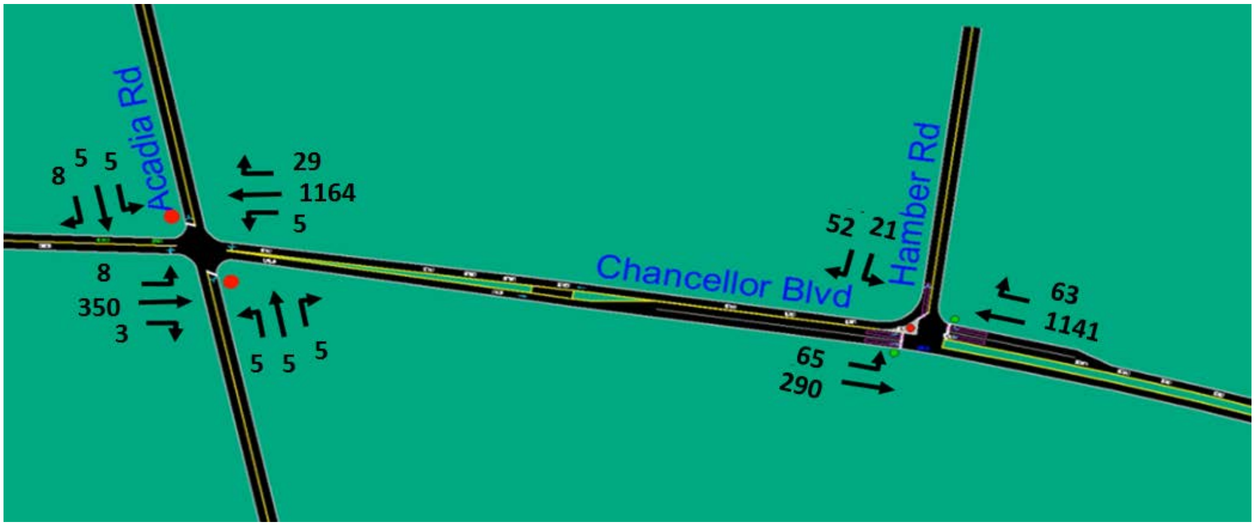

Figure 3 - Projected Traffic Volumes

4.1.2 Traffic Operations

4.1.2.1 Definitions

Operational results are based on the Highway Capacity Manual of 2000, which translates the average delay per vehicle into a level of service describing the flow conditions as summarized in Table 5 below

Level of Service (LOS)	Description	Average Control Delay Per Vehicle	
		Signalized Intersection	Unsignalized Intersection
A	Free Flow	≤10	≤10
B	Stable Flow (slight delays)	10 - 20	10 - 15
C	Stable flow (acceptable delays)	20 - 35	15 - 25
D	Approaching unstable flow	35 - 55	25 - 35
E	Unstable flow (intolerable delay)	55 - 80	35 - 50
F	Forced flow (jammed)	>80	>50

Table 5 - Level of Service Average Delay

4.1.2.2 Results

Synchro 6 software was used to determine operations along the Boulevard as well as at the intersections of Hamber and Acadia Roads. The analysis results are summarized in Table 6 below, with Synchro outputs provided in Appendix B.

	Existing (2018)				Future (2041)			
	Overall LOS	**V/C Ratio**	**Worst Movement**	**Worst Mov. av (s)**	**Overall LOS**	**V/C Ratio**	**Worst Movement**	**Worst Mov. av (s)**
Chancellor Blvd @ Acadia Rd	N/A	N/A	SBR	29	N/A	N/A	SBR	490
Chancellor Blvd @ Hamber Rd	N/A	N/A	N/A	N/A	A	0.75	SBL	36

Table 6 - Traffic Analysis Results

It is anticipated that at the peak hour (spanning 8:00-9:00 AM), southbound vehicles turning left from Acadia Rd onto Chancellor Blvd will experience the greatest delay, with that movement having an LOS of F. However, it is important to note that the model assumes that westbound vehicles along Chancellor Boulevard will be arriving at uniform distribution and that none will intentionally provide exit vehicles with sufficient gaps. In reality, it is likely that gaps will be provided and that westbound vehicles arrive in platoons due to the signal at Hamber Rd. Additionally, traffic will be most congested during the peak 15 minutes during which most pick-up-drop-off activity occurs at University Hill Elementary School along Hamber Rd.

4.1.3 Bicycle Operations

For the purposes of studying the operations of our study area in a multimodal fashion, we have considered the Highway Capacity Manual (HCM) 2010 formula for calculating the Bicycle Level of Service (BLOS). Based on the methodology as shown in Appendix B and the recommended geometric design of the road, the final score is calculated to be 3.45 while the current score is at 5.05, representing LOS C and F, respectively. It can therefore be concluded that the recommended design will be more conducive to cycling.

4.2 Underpass Structural Analysis

To ensure the safety of the users of the underpass, an in-depth structural analysis was carried out to design the underpass structures. All design components will follow the Canadian Standards Association (CSA) A23.3 codes for the design of concrete structures. For the underpass, it has been proposed to utilize cast-in-place concrete using a cut and fill construction method. The concrete structure will consist of two strip footings, two retaining walls designed as basement walls, and a one-way reinforced concrete slab serving as a bridge for the east and west ends of Chancellor Boulevard.

The following section will present the analysis methodology for each type of concrete structure. Results, such as dimensions and rebar placements, will be illustrated in the detailed design drawings found in Appendix I as well as in Section 5.2.

The given parameters for design are listed below:

Parameter	Value	Unit
Concrete Strength	25	MPa
Steel Strength	400	MPa
Concrete Resistance Reduction Factor	0.65	
Steel Resistance Reduction Factor	0.85	
Average Soil Weight	19	kN/m^3
Coefficient of Lateral Earth Pressure	0.5	
Maximum Soil Bearing Pressure	100	kPa

Table 7 - Design Parameters

4.2.1 Design Loadings

Before analyzing each structure, a design load must be determined as the maximum factored load for which the underpass must have the structural capacity for. Design loads will be calculated using the CSA S6-14 Section 3 Table 3.1. More specifically, loads will be calculated as indicated within the section and factored using the load combinations table.

4.2.1.1 Permanent Loads

The only permanent load considered will be the dead load since hydrostatic pressure is assumed to be non-existent due to proper drainage and secondary prestress effects are negligible. The dead load was calculated as the self-weight of the reinforced concrete slab as well as the road and its bases.

The self-weight will be calculated using 24.0 kN/m^3 across the area of the slab giving a distributed load of 14.4 kN/m.

4.2.1.2 Transitory Loads

The main transitory load will be contributed by the live load. Strain effects and settlement effects will be considered negligible using extra reinforcement as well as proper compaction. Wind loads will be ignored as the structure will be buried underground.

The live load was determined as the greater of a CL-625 truck or a factored CL-625 truck with a uniform load of 9kN/m. This is illustrated in Figure 4 and Figure 5.

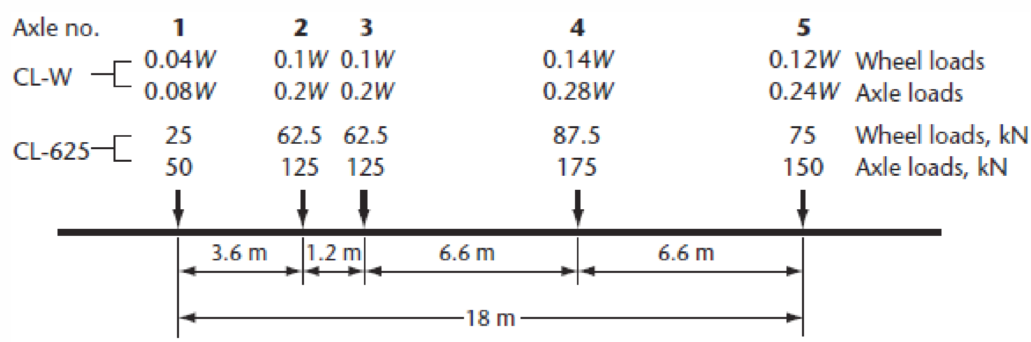

Figure 4 - CL-625 kN Truck Loading Case

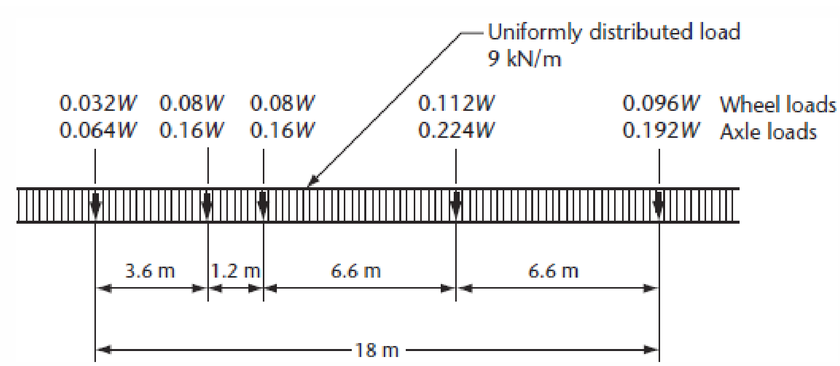

Figure 5 - Factored Truck Load with Distributed Loading

Axle and wheel loads were moved along the span of the slab to obtain a maximum bending moment and shear to be used as the live design load. This analysis was done with SkyCiv.

4.2.1.3 Exceptional Loads

Exceptional loads include earthquake, stream pressures, ice accretion loads, and collision loads. As these loads require extensive analysis, they will be ignored in the following analysis by using a factor of safety beyond the load factors.

4.2.1.4 Load Combinations

As mentioned previously, various load combinations were used to analyze the required design load. It was found that loading case Ultimate Limit State (ULS) Combination 1 governs. Furthermore, the governing axle and wheel locations for live loads were obtained using a pure CL-625 truck with its first axle and wheel at 0.1m from the left of the span. These iterations can be found in Appendix D. The final load combination yielded a total shear of 120 kN and total moment of 350 kNm. These values will be used to determine the reinforced concrete dimensions and reinforcements.

4.2.2 One-Way Slab Design

4.2.2.1 Flexural Reinforcement

Due to the restricted dimensions of the underpass, the slab on top will be proposed as a one-way slab. This means that the shear and moment analysis will only be considered in one direction and ignored for the other. This is a conservative conclusion as it is obvious the pedestrian underpass will be longer in one direction than the other. Following A23.3 Cl.9.8.2.1, the slab thickness was estimated to be the unsupported length of the slab divided by a factor of 20. The estimated slab thickness will also be the proposed slab thickness of 600mm. The required tension reinforcement was calculated using the following equation:

$$A_s = 0.0015 f_c' b(d - \sqrt{d^2 - \frac{3.85 M_r}{f_c' b}})$$

The calculated required area required was 1975 mm^2/m of slab length. Using 25M rebar (25mm in diameter and 500mm^2 in area), the required spacing was 250mm. This yields a total reinforcement area of 2000mm^2/m which is greater than the required.

To ensure this design is appropriate, the following checks were performed according to the CSA:

1. Reinforcement Ratio

Designing for a steel-controlled failure, where the rebar will fail before the concrete is ideal. This is due to the yielding of steel providing evacuation time and warning instead of the brittle failure of the crushing of concrete. The CSA A23.3 Cl.10.5.2 states that the reinforcement ratio of the design must be less than the balanced reinforcement ratio for the specified type of concrete. The designed reinforcement ratio is 0.0037 which is well below the required 0.022 balanced ratio.

2. Minimum Required Reinforcement

The CSA A23.3 Cl.7.8.1 specified a minimum amount of steel reinforcement according to the gross area of the concrete slab. This was calculated to be 0.002 of the gross area of concrete which was 538,000mm^2. This yields a minimum of 1076 mm^2 which is satisfied.

3. Maximum Bar Spacing

The CSA A23.3 Cl.7.8.1 specified a maximum bar spacing allowed in reinforced concrete slab design. This is calculated as the following:

$$s_{max} = min\begin{cases} 3h \\ 500 \end{cases}$$

It was calculated that the maximum bar spacing was 500mm which is satisfied.

4. Strength Requirement

The strength requirement is simply a check of the factored loads against the designed resistance. Our flexural design load of 350 kNm is satisfied.

5. Crack Control Parameter

Stated in A23.3 Cl.10.6.1, the crack control parameter must be satisfied to minimize cracking. This limit for exterior exposures is set at 25000 N/mm. This was initially not satisfied and caused a change in the spacing of rebar from 250 mm to 150 mm. The above checks were rechecked, and all conditions were satisfied if not better than before.

The last required design for the one-way slab is the shrinkage and temperature reinforcement as discussed in A23.3 Cl.7.8.1 and 7.8.3. Using the minimum required reinforcement stated above, and a spacing of

250 mm, the shrinkage and temperature reinforcement is designed to be 20M rebar (20 mm in diameter and 300 mm^2 in area.)

4.2.2.2 Shear Reinforcement

It is good practice to ensure that the shear resistance of the concrete slab be sufficient enough to satisfy the factored shear design load. In the proposed design, this was satisfied using a concrete shear resistance of 244 kN while the factored shear design load is 120 kN. Therefore, no steel shear resistance is required.

4.2.3 Basement Wall Design

The underpass walls will be designed as a reinforced concrete basement wall since it is subjected to both an axial load from the dead and live design loads as well as lateral loads from the soil pressure. The design first requires an estimated wall thickness. According to A23.3 Cl.14.3.6.1, this is estimated to be:

$$t = max\begin{cases} Unsupported\ wall\ height/25 \\ 190 \end{cases}$$

190 mm governs; however, the wall was designed with a thickness of 200 mm as good practice.

The basement wall must be reinforced for both flexural loads and shear loads which will be in the vertical and horizontal directions respectively.

4.2.3.1 Flexural Reinforcement

The flexural reinforcement for the underpass walls will be to resist the lateral soil earth pressures calculated to be 20.3 kNm/m of wall. Using the same equation for the one-way slab, a required reinforcement area of 405 mm^2/m will be used with a spacing of 500 mm.

Similar to one-way slab design, the following checks will be performed to ensure the design is appropriate.

1. **Maximum Bar Spacing**

According to A23.3 Cl.14.1.8.4, the maximum rebar spacing is defined as:

$$S_{max} = Min\begin{cases} 3t \\ 500 \end{cases}$$

500 mm governs; therefore, the condition is satisfied.

2. **Reinforcement Ratio**

Similar to above, the reinforcement ratio for the basement wall is 0.0027 which is below 0.022.

3. Minimum Required Reinforcement

According to A23.3 Cl.14.1.8.5, the minimum required reinforcement is defined as 0.0015 of the gross area of concrete. This yields a require reinforcement of 300mm^2 which is satisfied.

4.2.3.2 Shear Reinforcement

In the analysis of the underpass walls, shear reinforcement was not required since the concrete shear resistance was greater than the shear design load. However, it is good practice to include the minimum horizontal reinforcement for shear.

The minimum shear reinforcement will be designed using the minimum reinforcement area of 400mm^2/m and a spacing of 500mm. A detailed hand-calculation of this process can be found in Appendix D.

4.2.4 Strip Footing Design

To carry the design loads into the ground, footings are designed to ensure the design loads are probably transferred into the ground without exceeding the soil bearing capacity. The following analysis will be carried out according to CSA A23.3.

4.2.4.1 Footing Dimensions and Shear Reinforcement

The axial load per unit length on the footing will be the reaction on the foundation due to the dead and live design loads. The total factored axial load is 130 kN. The footing width will be calculated using the below equation:

$$l = \frac{P_S}{b * q_{all}} = 1.0\ m$$

With the factored axial load and area of the footing, the factored soil pressure is obtained with a value of 130 kPa.

Next, the footing thickness is estimated as 250 mm to test for the concrete shear resistance and compare it to the critical section for 1-way shear. A concrete resistance of 123 kN/m was calculated which satisfied the condition indicated in A23.3 Cl.11.2.8.1 since the factored shear load is only 28.6 kN/m.

4.2.4.2 Flexural Reinforcement

The required moment resistance was set equal to the factored moment from the soil bearing pressure. This was calculated as:

$$M_f = q_f \left(\frac{l-t}{2}\right)\left(\frac{l-t}{4}\right) b = 10.4\ kNm/m$$

Using the same equation as before, a required reinforcement area of 169 mm^2/m was calculated with a spacing of 400 mm.

Once again, checks are performed to ensure the design is appropriate.

1. **Minimum Reinforcement Area**

   Stated in A23.3 Cl.7.8.1, a minimum reinforcement area of 500 mm^2/m was calculated which is not satisfied. Therefore, this condition governs, and our designed reinforcement area will be 500 mm^2/m.

2. **Maximum Bar Spacing**

   Stated in A23.3 Cl.7.4.1.2 and Cl.13.10.4, the maximum permitted bar spacing is equal to the lesser of 3h and 500 mm. This condition is satisfied.

4.2.4.3 Longitudinal Reinforcement

Since the footings are designed using one-way conditions, the minimum reinforcement is provided for the longitudinal direction. This was calculated using the above stated clauses and yields a design of 600 mm^2 reinforcement area with a spacing of 500 mm.

The above analysis is the basis of our proposed underpass design. Once again, a complete description of the proposed underpass will be outlined in Section 5.2 with detailed design drawings for construction provided in Appendix I.

4.3 Geotechnical Analysis

A geotechnical analysis has been conducted along the roadway to determine the reliability of the roadway itself in settlement as well as the integrity of the underpass in terms of ground modification requirements as well as liquefaction and settlement.

4.3.1 Soil Profile

Borehole data from two locations, indicated in Figure 6 below, were made available to J3MRK Consulting from UBC Campus and Community Planning.

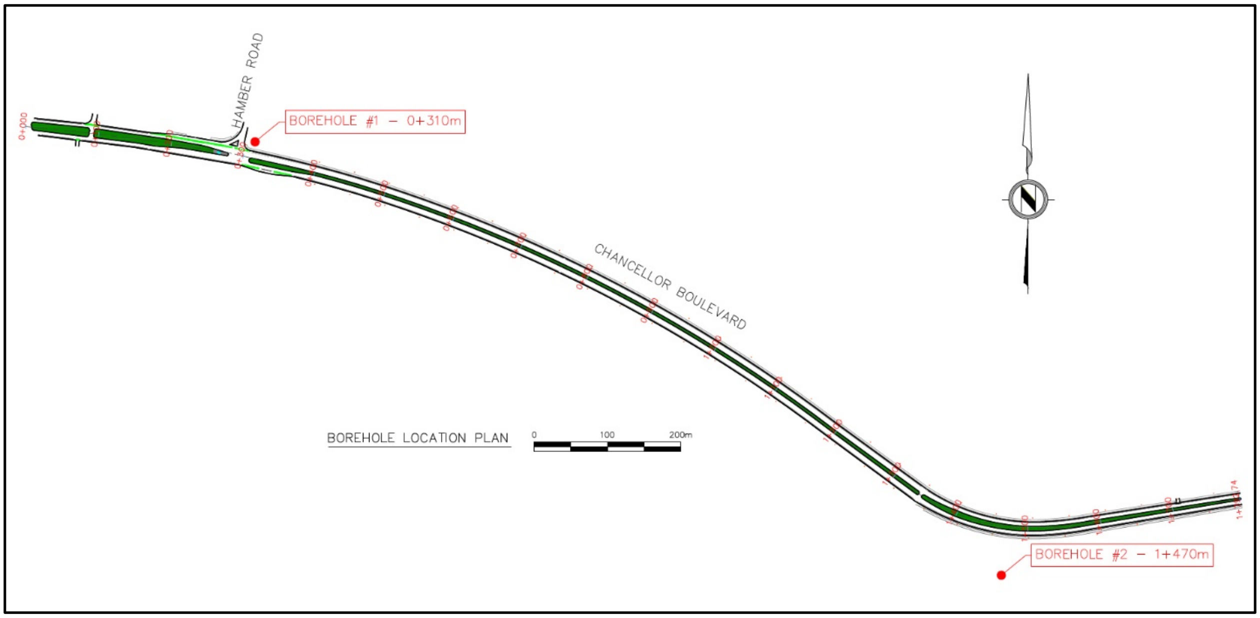

Figure 6 - Borehole Locations

The soil profile was therefore interpolated between the two boreholes (located at stations 0+310m and 1+470m respectively), spanning 1215 metres as shown below.

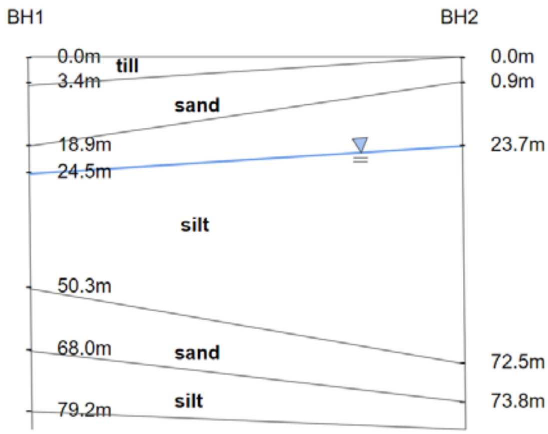

Figure 7 - Soil Profile

4.3.2 Footing Settlement

WB-20 → Design Vehicle. Based on the pedestrian underpass footings being placed on the sand layer near borehole #1 as shown in Figure 8 below, settlement calculations in sand and silt using the Schmertmann Strain Factor Method.

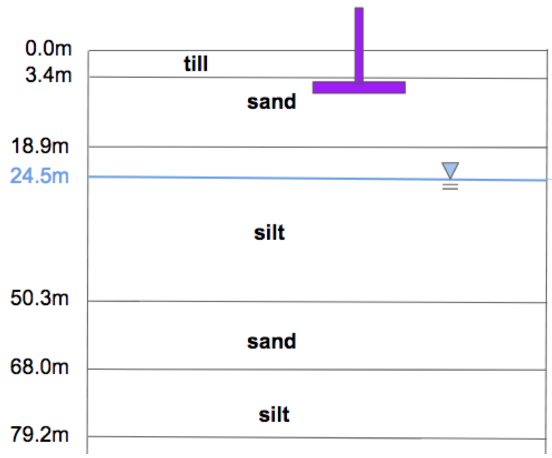

Figure 8 - Footing Settlement

A dead load of 14.4 kN/m was used based on the underpass dimensions and roadway assembly. A live load of 80 kN/m was calculated based on foot and vehicular traffic, assuming that traffic consists of 5% WB-20 trucks. Based on the NBCC 2010 load combinations, the maximum design load was calculated to be 138 kN/m. The assumptions made are the following:

- The soil strata beneath the footings is uniform with uniform parameters
- Water table is located 24.5 metres beneath the ground surface
- Elastic modulus of the soil is 15,000 kPa with a soil unit density of 19 kN/m3
- No organics are present in the soil

Using the ultimate limit state approach, $Load < Reduction\ Factor \times Capacity$, whereby a reduction factor of 0.5 is used and the soil ultimate bearing capacity is 200 kPa, the factor of safety for bearing capacity if 1.45.

Based on the strip footing design with a depth of 4.85 metres beneath ground surface, it is anticipated that the footings will settle relatively uniformly with a maximum differential settlement of 9 mm over a course of 5 years. This is well below the allowable general and differential settlement.

4.3.3 Recommended Ground Improvement

Ground improvement improves soil characteristics by increasing strength, decreasing permeability, reducing settlement, and increasing slope stability.

4.3.3.1 Underpass

In order to ensure that settlement is limited for the underpass footings, mechanical compaction of soil is recommended as a preventative measure.

4.3.3.2 Roadway

Given that the existing roadway is currently in use, no additional ground improvement is required when rebuilding sections which are already part of the utilized lane segments. For reconstructed segments of the road which will be built on loose sand or previously unloaded soil, roller compaction is recommended to limit the potential for pavement cracking and damage. The use of a mechanical vibratory roller is at the discretion of the City Engineer and is to be agreed upon with the BCMOTI.

5.0 Design Components

5.1 Geometric Design of Road

5.1.1 Overview of Corridor

Chancellor Boulevard is a 4-lane arterial bus route with posted speeds of 50 km/h to 60 km/h. Chancellor Boulevard serves as one of the main vehicle, bus and truck accesses into the Hamber Elementary and University of British Columbia.

5.1.2 Road Design

In the corridor's current conditions, excessive vehicle speeds are a significant safety concern due poor geometric road design. To counteract the excessive speeds along the corridor, various traffic calming measures are incorporated to increase safety throughout the corridor. Per Synchro analysis discussed in the previous section, one travel lane in each direction is sufficient for the traffic volume along Chancellor Boulevard; therefore, travel lanes have been reduced from two per direction to one per direction. Travel lanes have been designed to be 3.3m wide to discourage excessive speeding and to be in accordance to City of Vancouver standard widths for arterial bus routes. Speed limits will also be reduced to 50 km/h throughout the entire corridor.

5.1.3 Active Transportation Facilities

To encourage active transportation for users of all ages and abilities, 2.2m bike lanes have been incorporated into the road design in both directions of travel. In order to increase safety for cyclists travelling along the bike lane, 2.5m parking lanes and 1.0m buffers have been designed between the travel and bike lanes. This allows cyclists to be separated from the vehicles on the roadway, allowing less confident riders to be able to use the bike lane. A total of 280 parking spots have been added along the section of the corridor between Hamber Boulevard and Drummond Drive. To increase access to the numerous trails located along the corridor, a 2.0m wide sidewalk will be constructed on the north side of Chancellor Blvd between Hamber Rd and Drummond Dr. A pedestrian crossing will also be installed at the Spanish Trail entrances, located 450m west of Drummond Dr.

5.1.4 Hamber Intersection

Many significant changes have been made the the intersection of Chancellor Blvd and Hamber Rd to accommodate the addition of the proposed underpass. Specifics about the underpass design will be discussed in the next section. To encourage active transportation users to use the underpass rather than cross, the north-south pedestrian crosswalk on the west leg spanning Chancellor Blvd will be removed and a new east-west pedestrian crosswalk spanning Hamber Rd will be added to provide access to the proposed sidewalk. To account for heavy AM peak turning movements into Hamber Rd, the eastbound left turn lane has been maintained and a new westbound right turn lane has been added to avoid queueing after the road diet. In light of pedestrian and cyclist safety being such an important theme in the design, a concrete barrier physically separating the right-turning vehicles and cyclists in the bike lane has been added. Additionally, the westbound stop bar has been set back 3m to increase visibility of cyclists and pedestrians crossing the intersection.

5.2 Underpass

This section will be outline the final proposed underpass for the Hamber intersection both structurally as well as aesthetically. The structural analysis of the underpass was discussed in Section 4 and the detailed dimensions can be found in Appendix I. Other design components of the underpass are aimed to fulfill specific purposes which will be listed below:

1. Safety and the Sense of Security

   To promote user's sense of security while using the underpass, the use of natural lighting was utilized as well as a constant grade within the underpass such that all users will be able to see along the length of the underpass. Furthermore, an additional skylight will be provided in the midspan of the underpass to introduce natural lighting where it is commonly darkest. This is illustrated in Figure 9.

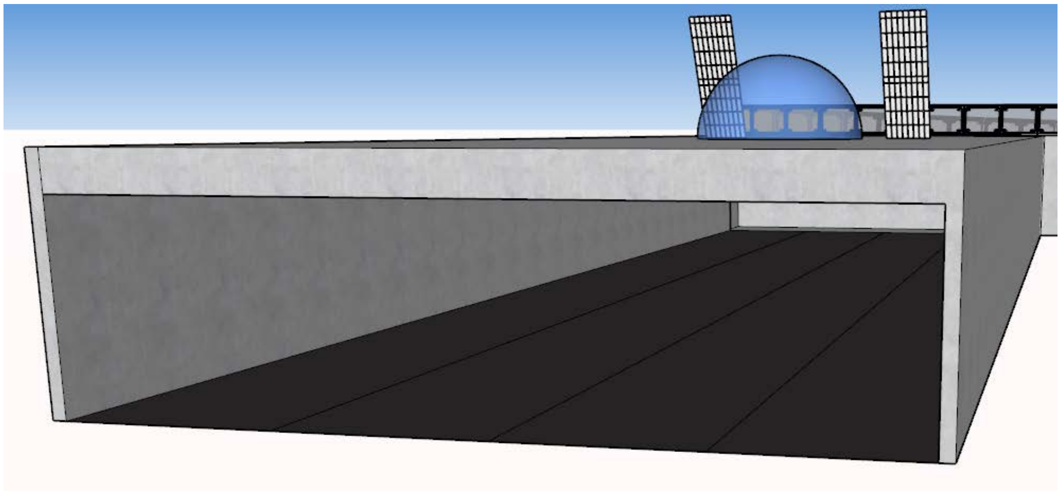

Figure 9 - Pedestrian Underpass Section View and Skylight

2. Convenience and Accessibility

The main purpose of the underpass is to provide a safe and accessible route for all non-automobile users. As seen in Figure 10, the ramps were designed according to the client specifications as well as the NBCC 2010. These ramps provide an abundant amount of space for all types of the users of the underpass while minimizing its impact on the surrounding environment with its spiralling design parallel to the road.

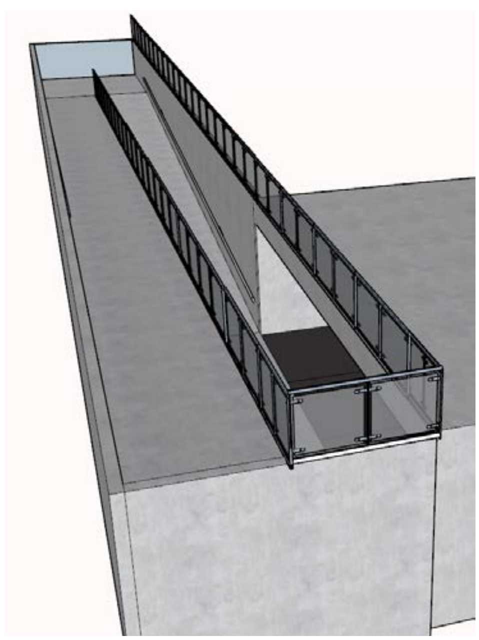

Figure 10 - Pedestrian Underpass Ramps

3. Sustainability

The underpass will be made using recycled concrete aggregate along with minimized amounts of steel rebar to minimize the impact on the surrounding environment. Also, the proposed underpass is fully underground which will further minimize the impact on the existing wildlife. It will also be proposed to install solar panels atop the underpass to ensure the power to the underpass is fully self-sustaining.

5.3 Utilities

5.3.1 Lighting

Lighting standards documented in the subsequent sections are based on the BC Ministry of Transportation and Infrastructure's Electrical & Traffic Engineering Design Guidelines. The aim of these guidelines is to produce accurate and comfortable vision along roadways at night while minimizing the required light pollution and energy consumption.

5.3.1.1 Roadway Lighting

The current stretch of roadway contains no street lighting apart from scarce intersection lighting at Hamber Road and Acadia Road. Given that ensuring pedestrian and cyclist safety is a major project design goal, the increase of street lighting is crucial to ensuring that vulnerable road users are visible past sunset. By applying the TAC and BC MOTI road lighting guidelines, it is determined that Chancellor Boulevard, which operates as an arterial road, would require 9-metre high davit luminaire poles with flat glass cobra head luminaires spaced at least 83 metres apart on either side of the roadway, with a 2.5 metre clearance from the vehicular travelled way. Lamps of 150W at a minimum luminance 13 lux are required as summarized in the Figure 11.

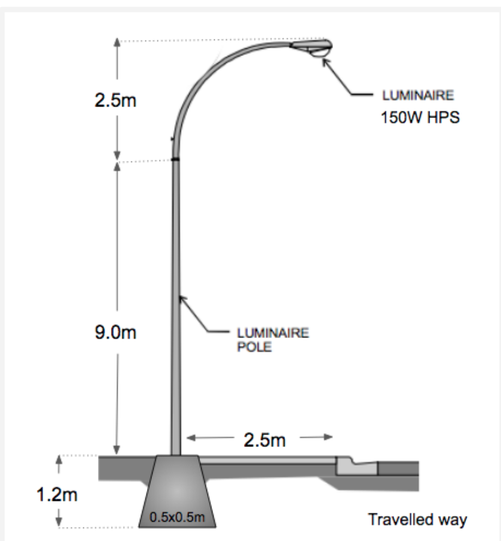

Figure 11 - Roadway Lighting

Because Chancellor Boulevard cuts through Pacific Spirit Regional Park, which is a highly-environmentally sensitive area, it is critical that these street lights only illuminate the road space but do not affect the surrounding park space. It is recommended that lighting fixtures that are shielded or provide cut-offs are used to limit the amount of light dispersed into the park. Additionally, lights of warmer colours (containing minimal colour within the blue wavelength spectrum) would prevent impact on migrating wildlife.

5.3.1.3 Power Connections

It is required that electrical conduits be extended along Chancellor Boulevard from Drummond Dr to Acadia Rd in order to provide lighting to the roadway. In accordance to municipal standards and for compatibility with the existing electrical conduits at Acadia Rd, it is required that they be 35mm rigid PVC conduits buried with a 1070mm cover beneath the roadway. Wiring should be stranded aluminum with RW90 insulation and colour coded per the Canadian Electrical Code (CEC).

5.3.1.4 Structural Lighting Components

Structural components of luminaires and lighting structures shall adhere to AASHTO's LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

5.3.2 Drainage

For drainage design, the Chancellor Blvd and Hamber Rd intersection was identified as the critical section and most vulnerable to flooding risk, especially with the proposed construction of the underpass at this intersection. Due to its subsurface location, the new tunnel will likely serve as a collection point during heavy storm events.

Metro Vancouver Regional IDF Curves produced by BCG Engineering Inc. were used in order to sufficiently estimate flood volumes and overland flow for the proposed project area. Specifically, our team utilized the IDF Curve for Zone 3, which includes the UBC area, as illustrated in Figure 12 below and Appendix E. In addition to these IDF Curves, a hydro-geotechnical study conducted by GeoAdvice Engineering Inc. for stormwater management at Chancellor Boulevard & NW Marine Drive established an estimated overland flow volume of $1016m^3$.

Thus, due to the close proximity (1.2km) and geophysical similarities between the intersections at Hamber Rd and NW Marine Dr, we assumed the same surface overflow volume for our drainage design in this report.

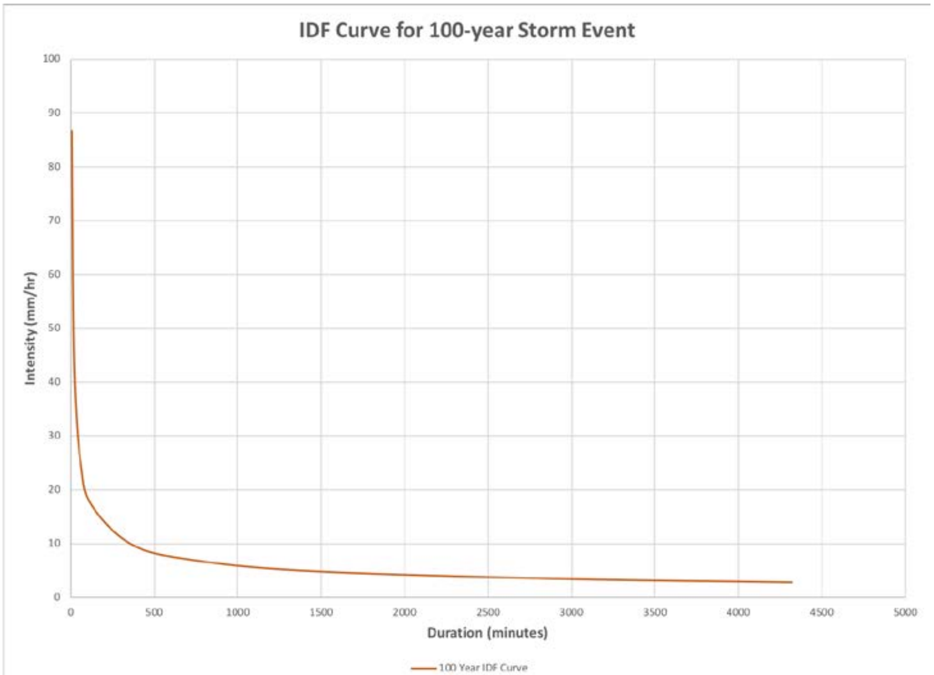

Figure 12 - IDF Curve for 100 year Storm Event in Zone 3 (BCG Engineering Inc., 2012)

Consequently, the drainage system has been designed to sustain the 1016m^3 100-year flood event. As illustrated in the storm sewer drawings in Appendix E, the tunnel drainage infrastructure includes two french drains with 800mm diameter perforated pipes. These pipes are 55m long and will run underneath the tunnel, adjacent to the footings. The proposed interceptor drains will collect groundwater and runoff from the saturated zone, diverting them straight into the outfall located North of the tunnel.

Furthermore, the tunnel surface infrastructure will be enhanced to effectively convey overland flows from runoff entering the tunnel bike lane/ ramp.

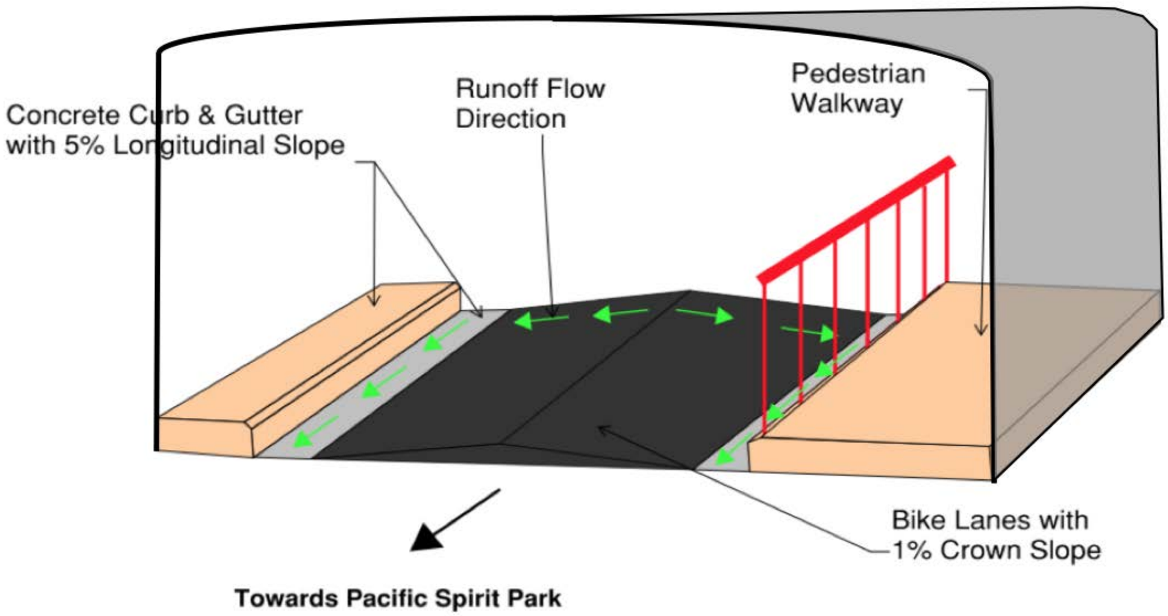

Figure 13 - Overland Flow Within Tunnel Drainage System

As illustrated in the Figure 13 above, the tunnel drainage system includes bike lanes with a 1% crown slope. This gravity enhanced flow directs rainfall runoff entering the tunnel towards the side curb and gutter which then directs flow down the 5% longitudinal slope towards Pacific Spirit Park, North of the Hamber intersection. This runoff will then be collected into the lawn basins which will then convey stormwater towards the outfall illustrated on Figure E-5 in Appendix E.

Other drainage design aspects include the use of porous asphalt and pervious concrete on proposed bike lanes and sidewalks to enhance infiltration capacity. Additionally, our design includes highly absorptive green infrastructure located in boulevards, road medians and surrounding vegetative areas. Runoff will percolate these infrastructure and will be conveyed into the perforated interceptor drains illustrated in Appendix E.

6.0 Construction Planning

This section of the report describes the proposed construction plan for the above mentioned project design. The plan involves the coordination of a multi-disciplinary set of resources, equipment, manpower, and specialized construction procedures. In addition to defining the required construction tasks, the sequence of each activity is also illustrated in the Project Schedule on Figure 15.

6.0.1 Pre-Construction Phase

The pre-construction phase includes various tasks that need to be completed prior to commencing the actual construction process. These invaluable tasks are listed below:

Phase	Action Items
Pre-Construction	● Apply for the permits (Ministry of Environment, MOTI, DFO) ● Stakeholder Engagement/ Consultation Meetings ● First Nations Consultation Meetings with Musqueam Community
Site Surveys & Investigations	● Geotechnical Analyses ○ Standard Penetration Tests (SPT) ○ Cone Penetration Tests (CPT) ○ Seismic CPT ○ Vane Shear Tests ○ Piezometric Pressures ○ Hydraulic Conductivity ○ Borehole sampling & Coring ○ Geophysical mapping & Contour-lining ○ Laboratory Tests: ■ Consolidation Tests ■ Permeability Tests ■ Shear Tests ○ Hydrogeologic Tests ● Utility Pre-locates: ○ BC One Call ○ Ground Penetrating Radar (GPR) pre-location of existing utilities ○ Utility Crossings/ Conflicts ● Traffic Analyses: ○ Traffic Counts ○ Synchro Analyses ○ Detours ○ Traffic Management Plans (TMPs) ● Procurement: ○ Construction Materials ○ Supplies ○ Equipment Rentals ○ Temporary Structures & Construction Devices (TSCDs)

Table 8 - Pre-Construction Phase

Assuming that the above-listed pre-construction activities and site investigations have already been completed, the following section outlines the main activities involved in executing the Tunnel and Road Construction Works as illustrated in the attached WBS and Project Schedule.

6.0.2 Mobilization of Equipment on Site

Project mobilization will take place on May 1st 2018. All project equipment, machinery, trucks, cranes, materials and personnel will be transported to the construction site. Road closures and night time mobilization will be required from 8pm (May 1st 2018) to 7am (May 2nd 2018) to facilitate the transportation of large machinery and equipment to the site.

6.0.3 Tunnel Construction

The work methods and tasks involved in the tunnel construction are described below:

- Site Preparation
    - Platform for site installations - this task involves setting up platforms that will facilitate necessary site installations including site offices, utilities, loading zones, crushing and processing stations, crew workstations, crane loading stations etc. These platforms must be installed in accordance to environmental regulations stipulated by the Ministry of Environment and Fisheries & Oceans Canada (DFO).
    - Site installations:
        - This task involves the re-routing of all overhead and underground utility lines/ conduits (existing water mains, power, electric, telecommunications, gas etc) that may interfere with the construction operations. There are two utility crossings at the Hamber Rd intersection, a 300mm Asbestos Cement water pipe and a 150mm Cast Iron water pipe.
        - As per the Surrey Design Criteria and Metro Vancouver (GVWD) minimum vertical clearance requirements, our crew will ensure that a minimum vertical clearance of 1m is maintained from the outer edge of the existing water mains to

the proposed tunnel roof. This is illustrated in the detailed utility crossing drawing in Appendix I.

- Detours & Road Closures:
  - This task involves the re-routing of traffic, road closures and any other Traffic Management Plans (TMPs) that will minimize any disruptions to the construction process whilst also providing viable alternative travel routes for motorists, cyclists and pedestrians. A temporary detour leading to U Hill Elementary School will be constructed for the entire duration of construction work. Additionally, Westbound traffic will be re-routed West on Blanca St and towards University Boulevard as illustrated in Figure F-2 of Appendix F.
  - The Site Plan on Figure F-1, and the TMP on Figure F-2, illustrate the spatial orientation and traffic routing/ detour plans to ensure public safety and enhance the efficient execution of this project.
- Site clearance procedure and temporary fencing - this task involves preparing/ clearing the site by removing vegetation and demolishing structures that may impede the construction process. This also involves erecting temporary fencing on Right of Way boundaries to protect the public from falling objects, moving trucks and other construction hazards.

- Excavation/ Earthworks
  - Surface Stripping/ Cutting - The cut & cover procedure selected for this project entails that the current road structure be milled, cut and stripped, thus removing existing asphalt, concrete, base and subbase layers at the tunnel “roof” location for the designed tunnel alignment.
  - Excavations - at this stage, heavy excavation equipment is used to remove all sand, gravel and rocks from the construction area. These excavated materials are stockpiled in heaps as suitable or unsuitable materials. The suitable material is kept on site for reuse during the backfilling stage, while the unsuitables are transported offsite.

  - Temporary Structures & Construction Devices (TSCDs) - temporary construction structures such as scaffolding and shoring are erected to mechanically stabilize the “roof” and “walls” of the proposed tunnel area. This ensures the safe and efficient execution of underground construction work by workers and machinery. Emergency evacuation and other safety procedures are also established, with all workers trained accordingly.
  - Backfill - this task involves refilling excavated zones with suitable rock and gravel materials. The backfill is subsequently compacted by rollers/ packers to ensure sufficient backfill shear capacity. This happens at various stages of the construction project.
- Dewatering - this task involves employing effective groundwater control measures to minimize water seepage into the construction zone. This is done by installing a network of pipes that direct ground water away from the construction zone towards the Georgia Straight. This may also include the erection of membranes/ walls that minimize water ingress to the construction zone.
- Embankment & Retaining Wall Installation - this task focuses on mechanically stabilizing the tunnel “walls” and prevents unsupported soil from collapsing into the tunnel. The designed MSE Retaining Walls are erected on both longitudinal sides of the tunnel. They are subsequently backfilled with suitable rock and gravel which are either trucked from an offsite quarry or reclaimed from previously excavated suitable stockpiles. The detailed Retaining Walls are illustrated in Appendix I.
- Installation of Storm Drainage Infrastructure - this task involves installing the proposed stormwater, overland flow curb and gutter, and catch basins to effectively drain the project site. Specific drainage details are described in Section 5.3.2 of this report.
- Installation of Tunnel Foundation/ Footings - after the site has been levelled off, a reinforced concrete strip footing will be casted on both sides of the underpass. 20 cubic meters of concrete will be cast in place over a rigid network of reinforcing steel to build this strong and economical foundation.
- Installation of Tunnel Roadworks:

- Base/ Sub-base/ Paving - this task involves the preparation of the tunnel "floor" by placing suitable rock and gravel in the base and subbase layers of the underpass roadway.
- Curb & Gutter - this task involves installing the required curb and gutter infrastructure for effective drainage. The curb and gutter assembly is further described in Section 5.3.2 of this report.
- Guardrail Installation - this task involves the installation of 130m of steel guardrails within the tunnel as well as the access ramps.
- Line painting & Signage - as a finishing step to constructing the underpass roadway, line painting and the erection of signage will follow the project schedule..

- Concrete Pouring - to facilitate the above mentioned foundation pour, roadworks and other cast-in place requirements, various transit mix pump trucks will be scheduled to facilitate an efficient continuous pour.
- Tower Crane Assembly - this task involves the erection of the tower crane used to lift the tunnel (precast) superstructure into place. This work is done onsite.
- Installation of Modular Tunnel Superstructure
  - The precast modular tunnel superstructure is crane-lifted to position, equipped with holes and slots for all required conduits and utilities.
  - Shotcreting & Tunnel Waterproofing - this task involves spraying the inner tunnel surface with shotcrete. This solidifies the tunnel lining, providing sufficient rigidity and strength. The tunnel lining is also covered with a waterproofing membrane to seal the tunnel from unwanted water seepage.
  - Ventilation System - this task involves the installation of the ventilation chamber, ducts and other required mechanical systems.
  - Solar Panels - solar panels are also installed at both tunnel entrances to power the LED lights illuminating the tunnel.
  - Lighting System - the LED lighting system is installed by onsite electricians

- Construction of North & South Ramps - this task involves the grading, backfilling, paving and line painting of the North & South access ramps to the tunnel. The detailed drawing is illustrated in Appendix I.
- Fence Installation - as part of the construction finishing process, this task involves erecting fences along the sides of the ramps to guide users along the tunnel crossing. The fence also prevents users from crossing the road above ground, thus minimizing the potential for accidents.
- Hydroseeding - as part of the construction finishing process, hydroseeding involves turfing/ vegetating the slopes/ backfill adjacent to the tunnel to minimize erosion.

6.0.4 Road Works

The work methods and tasks involved in the road construction process are described below:

- Crossing Removal - this task involves removing the pedestrian crossing at the Hamber Road intersection. This includes eliminating all signage and crosswalk infrastructure.
- Boulevard Expansion - this task involves the general expansion of road medians or "boulevard" as per the geometric designs. The additional green spaces will improve the drainage and infiltration capacity of this corridor. This task also involves the placing of concrete to extend the existing East-West median at Hamber Road such that it covers the previous crosswalk location. This median will include median planters and a skylight as described below. See Appendix I for more detailed drawings.
- Skylight Installation - this involves the installation of the designed skylight on the tunnel roof. The fiberglass panels will be installed on the median directly above the tunnel cap.
- Road Milling & Paving - This task involves the milling of deteriorated asphalt and the re-surfacing / repaving of the existing roadway with asphalt. Bike lanes and sidewalks will be surfaced with porous asphalt and pervious concrete to enhance the infiltration and drainage capacity of the site.
- Bike Lanes - As mentioned in the design description, the two-lane roadway will be converted to a one-way motorist lane with a separated bike lane on both longitudinal stretches of Chancellor Boulevard.

- Parking Spots - this task involves the installation of additional parking spots as described in the geometric design section. See Appendix I
- Line Painting - this task involves the painting of bike lanes, buffer zones, parking spots and other standard road markings on the newly paved road
- Signage installation - this task involves the installation of new traffic signs for bike lanes, tunnel, and reinstated bus stop sign.
- Catch Basin Installation - this task includes the installation of additional catch basins and lawn drains to improve the drainage capacity at the Hamber Rd intersection.
- Lighting - this task involves the installation of new lighting infrastructure to better illuminate the area around the tunnel.

6.1 Work Breakdown Structure (WBS)

The construction tasks described in Section 6.0 are presented in the WBS below:

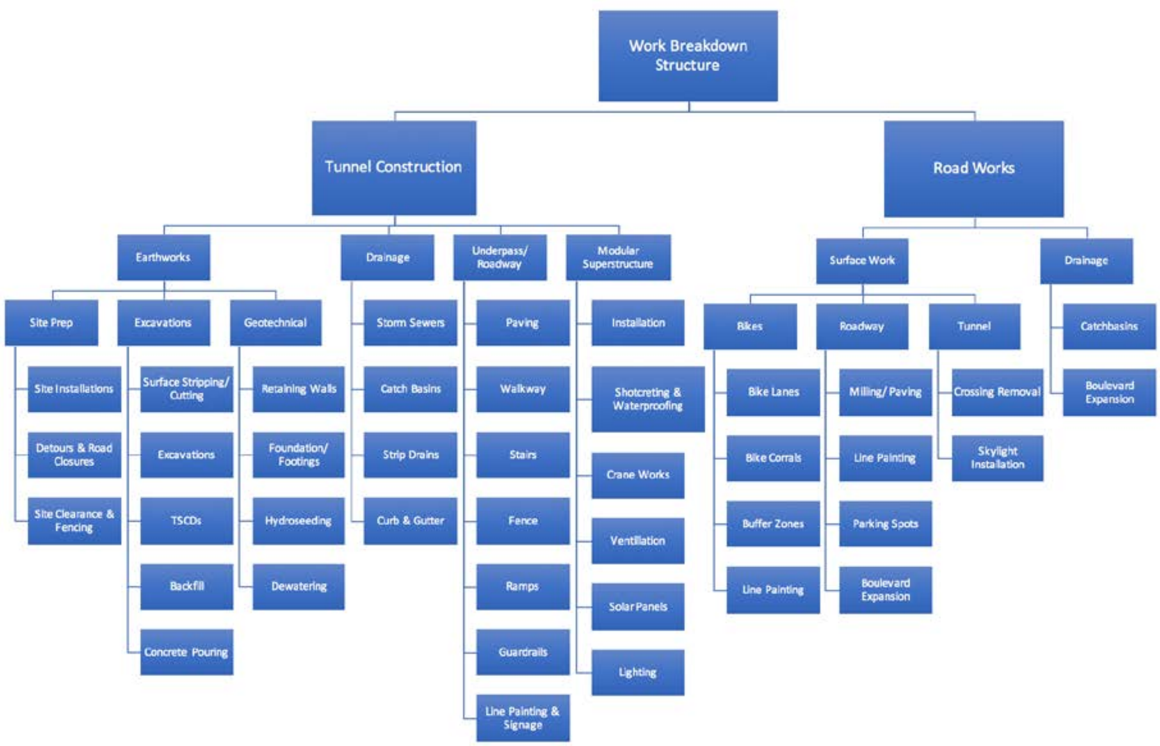

Figure 14 - Work Breakdown Structure

6.2 Project Schedule

The Project Schedule below illustrates the sequence and duration of all proposed construction activities, starting from the procurement stage until project completion and demobilization off-site.

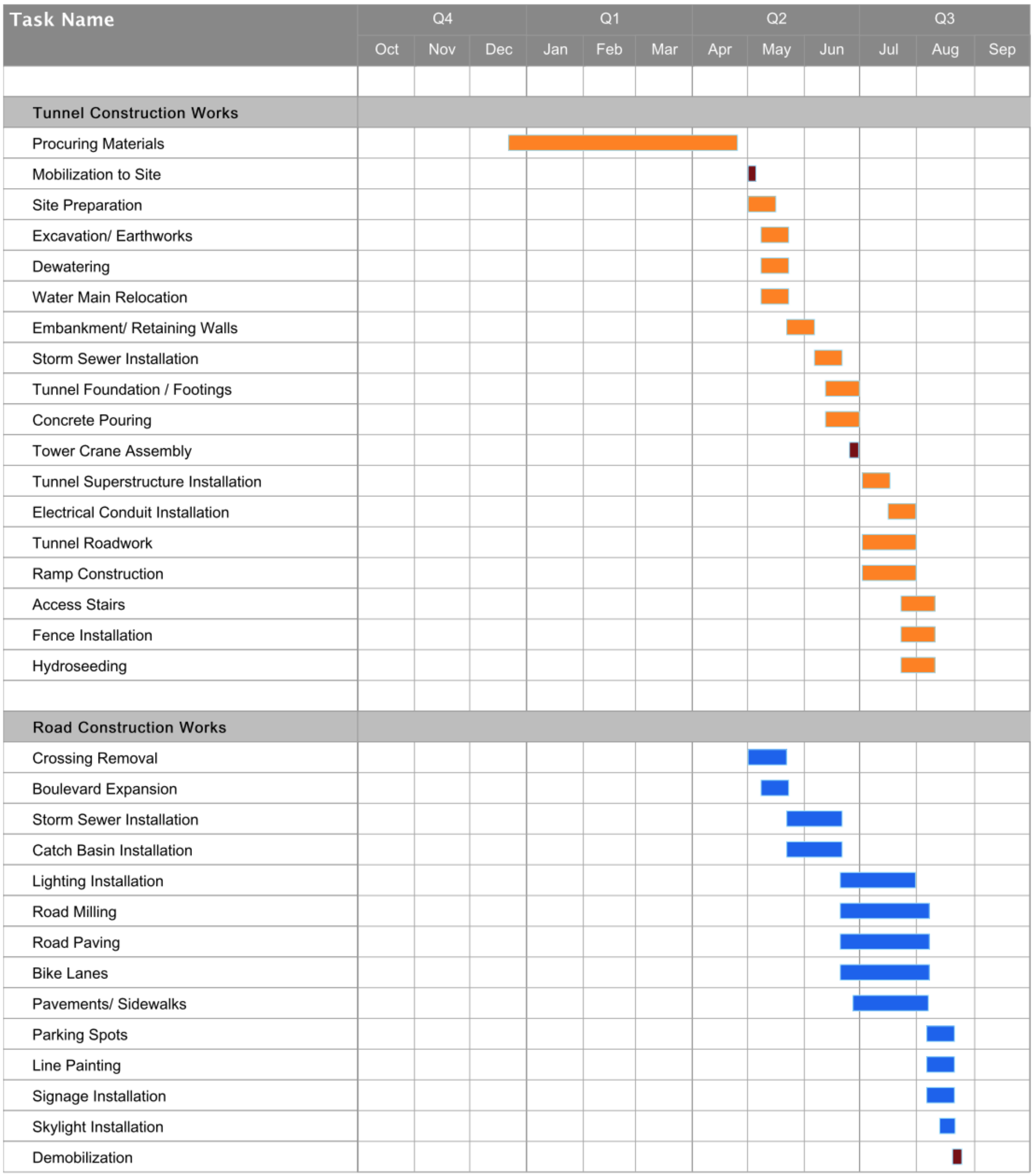

Figure 15 - Detailed Project Schedule

7.0 Cost Estimate

The anticipated total project cost is $5.21 million. This cost estimate is comprised of project management, planning, design and construction costs. A general cost breakdown can be found in the figure below. The detailed cost breakdown can be found in Appendix G.

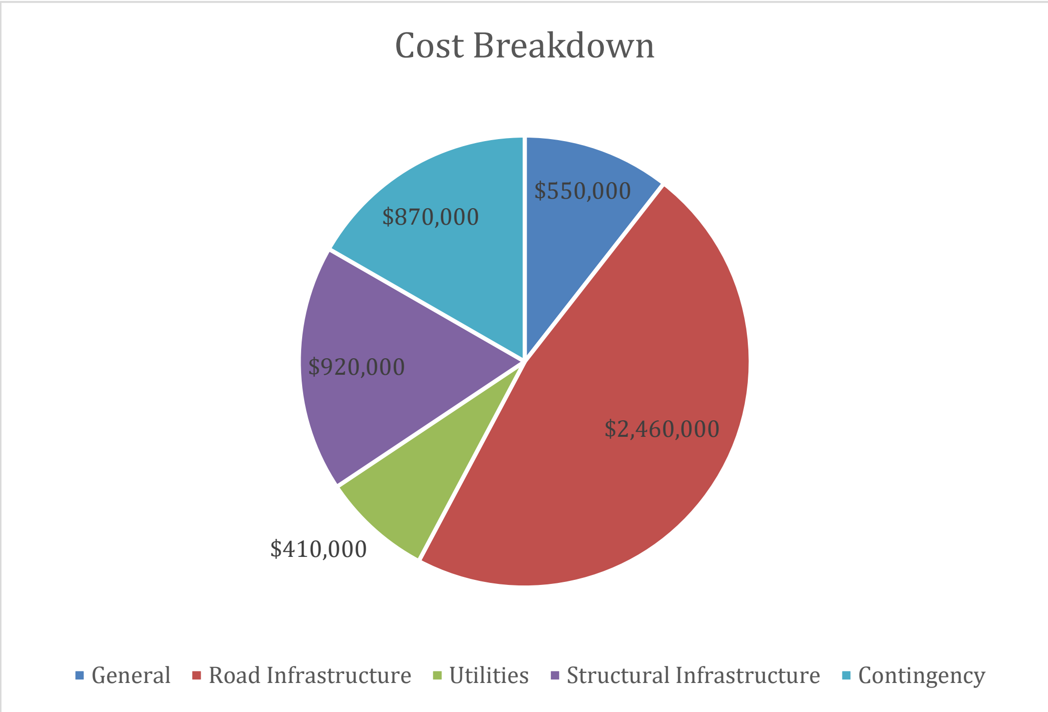

Figure 16 – General Cost Breakdown

8.0 Maintenance Plan

Given that one of the main design issues that the redesign aims to solve is the disrepair of active transportation amenities, a maintenance plan is provided to ensure that the corridor will be kept at an optimal state. Using a year by year breakdown, expenses are allocated according to minor and major expenses. Minor expenses include tasks such as repainting light poles, which major expenses include tasks such as resurfacing the road. The total present worth cost of the maintenance until 2118 is expected to be $5,330,000, with an estimated rate of inflation of 2%. The maintenance plan can be found in Appendix H.

9.0 References

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Appendix A: Stakeholder Engagement

Stakeholder	Method of Contact	Concerns Relayed
UBC SEEDS Sustainability Program	Formalized Consultations, Town Hall	Increasing sustainability of the environment Minimizing negative impacts on environment
UBC Students, Faculty, and Staff	Town Hall	Minimizing road closures and maximizing access to outside of UBC Aesthetics of the corridor
Ministry of Transportation and Infrastructure	Formalized Consultations	Usability and safety of the road
TransLink	Formalized Consultations	Roadwork effects on bus routing
University Endowment Land Residents	Formalized Consultations, Town Hall	Minimizing road closures and maximizing access to outside of UBC Aesthetics of the corridor Walkability of the corridor
University Neighbourhood Association	Formalized Consultations, Town Hall	Wanting to enhance livability of the space
Chancellor Place Neighbourhood	Town Hall	Minimizing road closures Aesthetics
Musqueam First Nations	Musqueam Indian Band visit (Musqueam, n.d.), Formalized consultations	Want to have their opinions heard and consulted Minimizing impacts to the environment Corridor should not negatively affect their way of life
UBC Building Operations	Town Hall	Ease of maintenance is importance Access for official vehicles

Table A - 1 – Project Stakeholders

J3MRK Consulting

TOWN HALL MEETING

MARCH 5, 2018

UBC CEME 2202

TOPIC OF DISCUSSION:

CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

FREE AND OPEN TO THE PUBLIC

UBC SOCIAL ECOLOGICAL ECONOMIC DEVELOPMENT STUDIES (SEEDS) SUSTAINABILITY PROGRAM

Figure A - 1 - Town Hall Meeting Poster

Appendix B: Transportation Analysis & Synchro Results

The Bicycle Level of Service was calculated by using the Highway Capacity Manual (HCM) 2010

formula at the link level which is given as follows: $I_{b,link} = 0.760 + F_w + F_v + F_S + F_p$ where the parameters can be calculated as follows:

$F_w = -0.005W_e^2$	$W_e = W_v + W_{bl} + W_{os}^* - 20\ p_{pk} \geq 0.0$ Where Wv= effective total width of outside through lane, bicycle lane, and shoulder as a function of traffic volume (ft), Wbl= bike lane width (ft), Wos= width of paved outside shoulder (ft), and Ppk= parking occupancy.
$F_v = 0.507 \ln\left(\frac{v_{ma}}{4N_{th}}\right)$	Where Vma is the midsegment demand flow rate (veh/hr), and Nth is the number of through lanes in the direction of travel
$F_S = 0.199\,(1.1199\ln(S_{Ra} - 20) + 0.8103)\,(1 + 0.1038P_{HVa})^2$	Where SRa is vehicle running speed (Mi/hr), and PHVa is the proportion of heavy vehicles.
$F_p = \frac{7.066}{P_c^2}$	Where Pc is the pavement condition rating between 1 and 5.

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations		↑↑	↑↑			
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)						
Lane Util. Factor						
Frt						
Flt Protected						
Satd. Flow (prot)						
Flt Permitted						
Satd. Flow (perm)						
Volume (vph)	0	0	0	0	0	0
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	0	0
RTOR Reduction (vph)	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	0	0
Turn Type						
Protected Phases		4	8			
Permitted Phases						
Actuated Green, G (s)						
Effective Green, g (s)						
Actuated g/C Ratio						
Clearance Time (s)						
Lane Grp Cap (vph)						
v/s Ratio Prot						
v/s Ratio Perm						
v/c Ratio						
Uniform Delay, d1						
Progression Factor						
Incremental Delay, d2						
Delay (s)						
Level of Service						
Approach Delay (s)		0.0	0.0		0.0	
Approach LOS		A	A		A	

Intersection Summary			
HCM Average Control Delay	0.0	HCM Level of Service	A
HCM Volume to Capacity ratio	0.00		
Actuated Cycle Length (s)	20.0	Sum of lost time (s)	0.0
Intersection Capacity Utilization	0.0%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Volume (veh/h)	14	268	2	0	892	22	0	0	0	0	0	6
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	15	291	2	0	970	24	0	0	0	0	0	7
Pedestrians												
Lane Width (m)												
Walking Speed (m/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (m)					292							
pX, platoon unblocked	0.59						0.59	0.59		0.59	0.59	0.59
vC, conflicting volume	993			293			1299	1316	292	1292	1293	970
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	989			293			1504	1533	292	1493	1495	949
tC, single (s)	4.1			4.1			7.1	6.5	6.2	7.1	6.5	6.2
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	96			100			100	100	100	100	100	97
cM capacity (veh/h)	414			1268			55	66	747	59	70	187

Direction, Lane #	EB 1	WB 1	WB 2	WB 3	NB 1	SB 1
Volume Total	309	0	970	24	0	7
Volume Left	15	0	0	0	0	0
Volume Right	2	0	0	24	0	7
cSH	414	1700	1700	1700	1700	187
Volume to Capacity	0.04	0.00	0.57	0.01	0.00	0.03
Queue Length 95th (m)	0.9	0.0	0.0	0.0	0.0	0.8
Control Delay (s)	1.3	0.0	0.0	0.0	0.0	24.9
Lane LOS	A				A	C
Approach Delay (s)	1.3	0.0			0.0	24.9
Approach LOS					A	C

Intersection Summary			
Average Delay	0.4		
Intersection Capacity Utilization	56.9%	ICU Level of Service	B
Analysis Period (min)	15		

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0		4.0	
Lane Util. Factor	1.00	0.95	0.95		1.00	
Frt	1.00	1.00	0.99		0.90	
Flt Protected	0.95	1.00	1.00		0.99	
Satd. Flow (prot)	1789	3579	3551		1677	
Flt Permitted	0.26	1.00	1.00		0.99	
Satd. Flow (perm)	499	3579	3551		1677	
Volume (vph)	50	226	874	48	16	40
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	54	246	950	52	17	43
RTOR Reduction (vph)	0	0	10	0	25	0
Lane Group Flow (vph)	54	246	992	0	35	0
Turn Type	Perm					
Protected Phases		4	8		6	
Permitted Phases	4					
Actuated Green, G (s)	15.1	15.1	15.1		16.0	
Effective Green, g (s)	15.1	15.1	15.1		16.0	
Actuated g/C Ratio	0.39	0.39	0.39		0.41	
Clearance Time (s)	4.0	4.0	4.0		4.0	
Vehicle Extension (s)	3.0	3.0	3.0		3.0	
Lane Grp Cap (vph)	193	1382	1371		686	
v/s Ratio Prot		0.07	c0.28		c0.02	
v/s Ratio Perm	0.11					
v/c Ratio	0.28	0.18	0.72		0.05	
Uniform Delay, d1	8.3	7.9	10.2		7.0	
Progression Factor	1.00	1.00	1.00		1.00	
Incremental Delay, d2	0.8	0.1	1.9		0.1	
Delay (s)	9.1	8.0	12.1		7.1	
Level of Service	A	A	B		A	
Approach Delay (s)		8.2	12.1		7.1	
Approach LOS		A	B		A	

Intersection Summary			
HCM Average Control Delay	11.0	HCM Level of Service	B
HCM Volume to Capacity ratio	0.38		
Actuated Cycle Length (s)	39.1	Sum of lost time (s)	8.0
Intersection Capacity Utilization	42.4%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Volume (veh/h)	0	0	0	0	0	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	0	0	0	0	0	0
Pedestrians						
Lane Width (m)						
Walking Speed (m/s)						
Percent Blockage						
Right turn flare (veh)						
Median type					None	
Median storage veh)						
Upstream signal (m)		115				
pX, platoon unblocked						
vC, conflicting volume	0				0	0
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	0				0	0
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	100				100	100
cM capacity (veh/h)	1623				1023	1085

Direction, Lane #	EB 1	WB 1	SB 1
Volume Total	0	0	0
Volume Left	0	0	0
Volume Right	0	0	0
cSH	1700	1700	1700
Volume to Capacity	0.00	0.00	0.00
Queue Length 95th (m)	0.0	0.0	0.0
Control Delay (s)	0.0	0.0	0.0
Lane LOS			A
Approach Delay (s)	0.0	0.0	0.0
Approach LOS			A

Intersection Summary			
Average Delay	0.0		
Intersection Capacity Utilization	0.0%	ICU Level of Service	A
Analysis Period (min)	15		

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Volume (veh/h)	8	350	2	0	1164	29	0	0	5	0	0	8
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	9	380	2	0	1265	32	0	0	5	0	0	9
Pedestrians												
Lane Width (m)												
Walking Speed (m/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (m)					292							
pX, platoon unblocked	0.23						0.23	0.23		0.23	0.23	0.23
vC, conflicting volume	1297			383			1689	1696	382	1685	1681	1281
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	2270			383			3947	3978	382	3933	3915	2203
tC, single (s)	4.1			4.1			7.1	6.5	6.2	7.1	6.5	6.2
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	83			100			100	100	99	100	100	34
cM capacity (veh/h)	52			1176			0	1	666	0	1	13

Direction, Lane #	EB 1	WB 1	NB 1	SB 1
Volume Total	391	1297	5	9
Volume Left	9	0	0	0
Volume Right	2	32	5	9
cSH	52	1176	666	13
Volume to Capacity	0.17	0.00	0.01	0.66
Queue Length 95th (m)	4.1	0.0	0.2	11.8
Control Delay (s)	20.1	0.0	10.5	496.6
Lane LOS	C		B	F
Approach Delay (s)	20.1	0.0	10.5	496.6
Approach LOS			B	F

Intersection Summary			
Average Delay	7.2		
Intersection Capacity Utilization	73.0%	ICU Level of Service	D
Analysis Period (min)	15		

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0	4.0	4.0	
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	
Frt	1.00	1.00	1.00	0.85	0.90	
Flt Protected	0.95	1.00	1.00	1.00	0.99	
Satd. Flow (prot)	1789	1695	1883	1441	1678	
Flt Permitted	0.14	1.00	1.00	1.00	0.99	
Satd. Flow (perm)	265	1695	1883	1441	1678	
Volume (vph)	65	290	1141	63	21	52
Peak-hour factor, PHF	0.75	0.92	0.92	0.75	0.75	0.75
Adj. Flow (vph)	87	315	1240	84	28	69
RTOR Reduction (vph)	0	0	0	14	64	0
Lane Group Flow (vph)	87	315	1240	70	33	0
Parking (#/hr)		0		0		
Turn Type	Perm			Perm		
Protected Phases		4	8		6	
Permitted Phases	4			8		
Actuated Green, G (s)	66.3	66.3	66.3	66.3	6.2	
Effective Green, g (s)	66.3	66.3	66.3	66.3	6.2	
Actuated g/C Ratio	0.82	0.82	0.82	0.82	0.08	
Clearance Time (s)	4.0	4.0	4.0	4.0	4.0	
Vehicle Extension (s)	3.0	3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	218	1396	1551	1187	129	
v/s Ratio Prot		0.19	c0.66		c0.02	
v/s Ratio Perm	0.33			0.05		
v/c Ratio	0.40	0.23	0.80	0.06	0.26	
Uniform Delay, d1	1.9	1.5	3.7	1.3	35.0	
Progression Factor	1.00	1.00	1.00	1.00	1.00	
Incremental Delay, d2	1.2	0.1	3.0	0.0	1.1	
Delay (s)	3.1	1.6	6.7	1.3	36.0	
Level of Service	A	A	A	A	D	
Approach Delay (s)		1.9	6.3		36.0	
Approach LOS		A	A		D	

Intersection Summary			
HCM Average Control Delay	6.9	HCM Level of Service	A
HCM Volume to Capacity ratio	0.75		
Actuated Cycle Length (s)	80.5	Sum of lost time (s)	8.0
Intersection Capacity Utilization	71.1%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group

Appendix C: Geometric Road Design

The following figures show the proposed typical geometric road design. The proposed parking lanes serve as a protective barrier for the bike lane. In addition, the location of the sidewalk and multi-use pathway is shown as well.

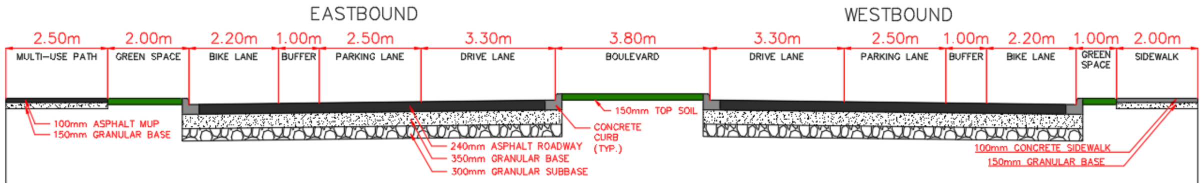


Figure C - 1 - Typical Road Profile

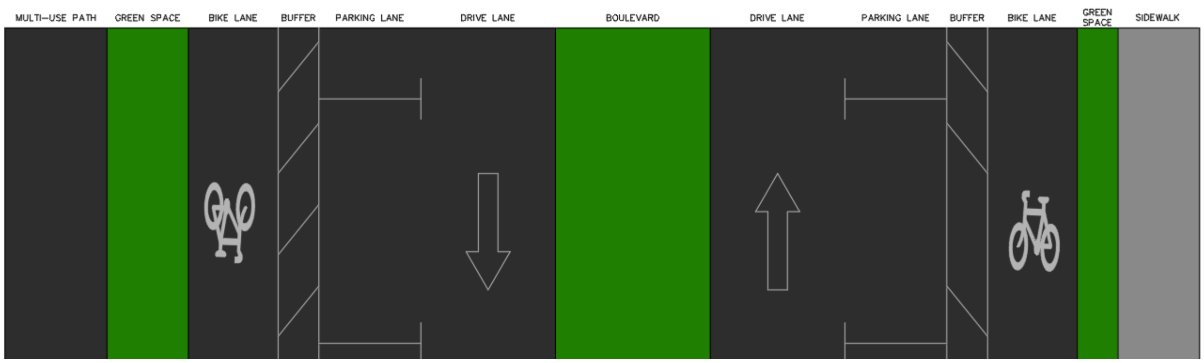


Figure C - 2 - Typical Road Plan

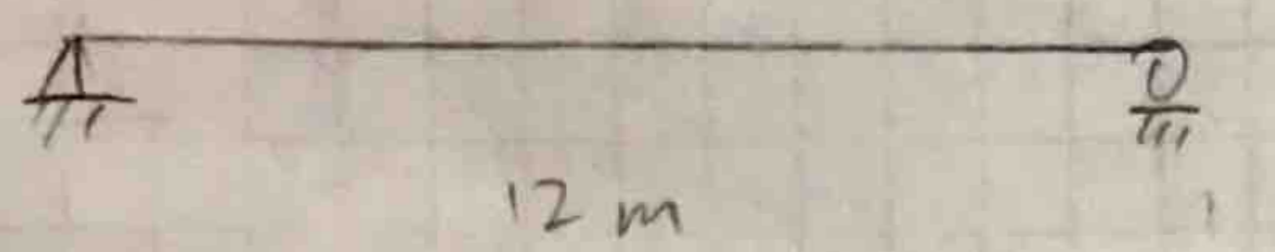
Appendix D: Underpass Calculations

Chanc. Blvd Pedestrian Underpass - Design Loads

Bridge Span

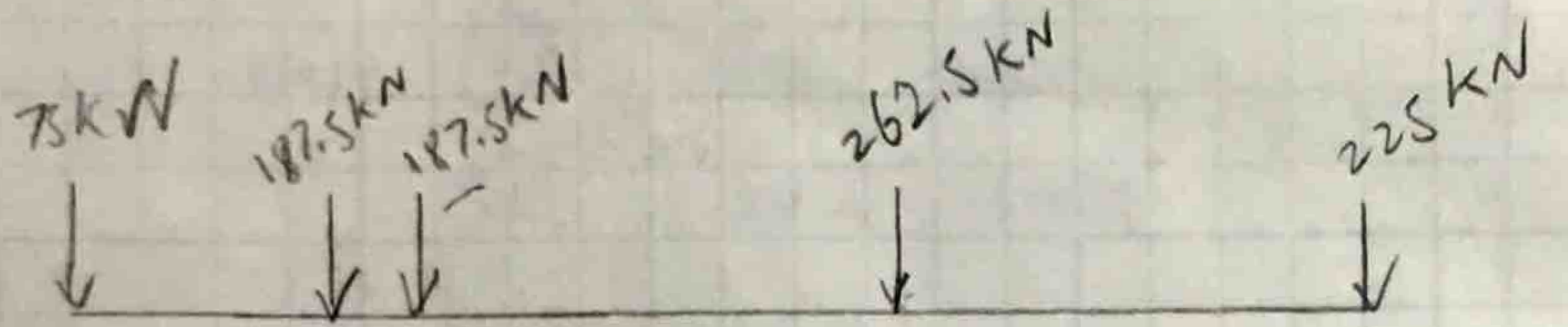
Unit weight

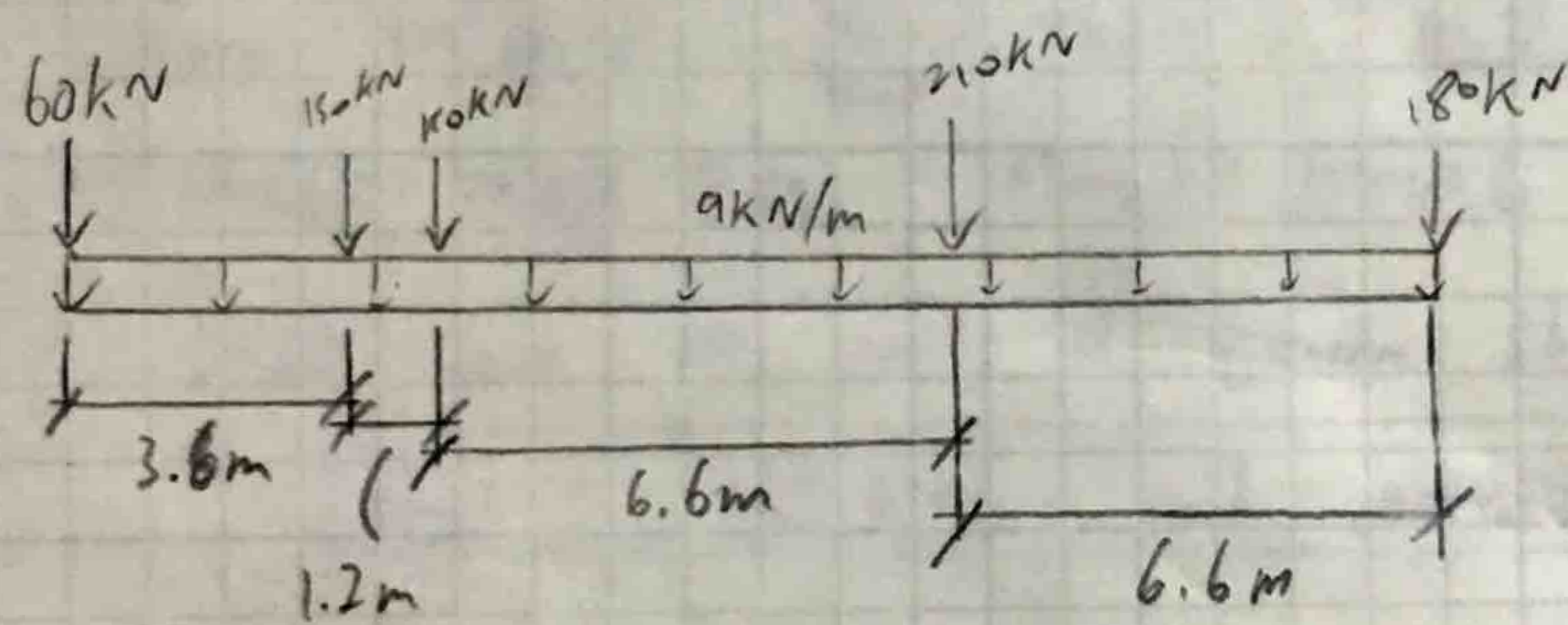
R.C. 24 kN/m³



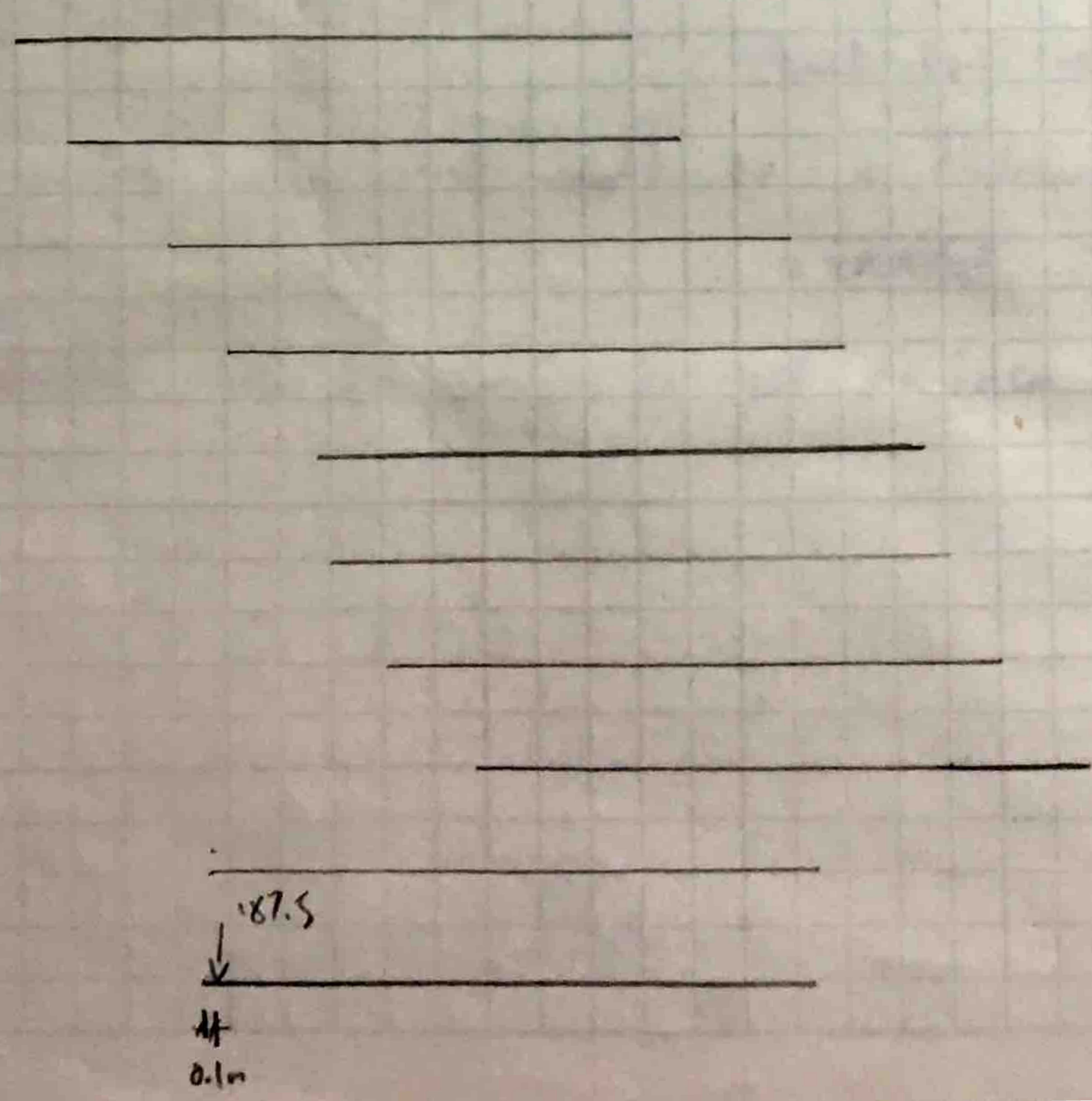
Curb-to-curb is 27m

CSA 3.8.3.1.1 CL-625 Loading and CSA 3.8.3.1.2 Lane loads

① 

② 

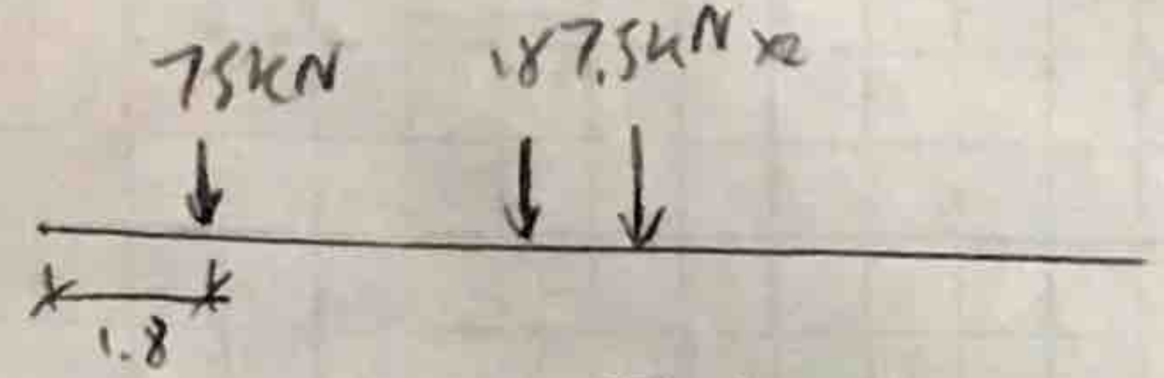
Load Scenarios



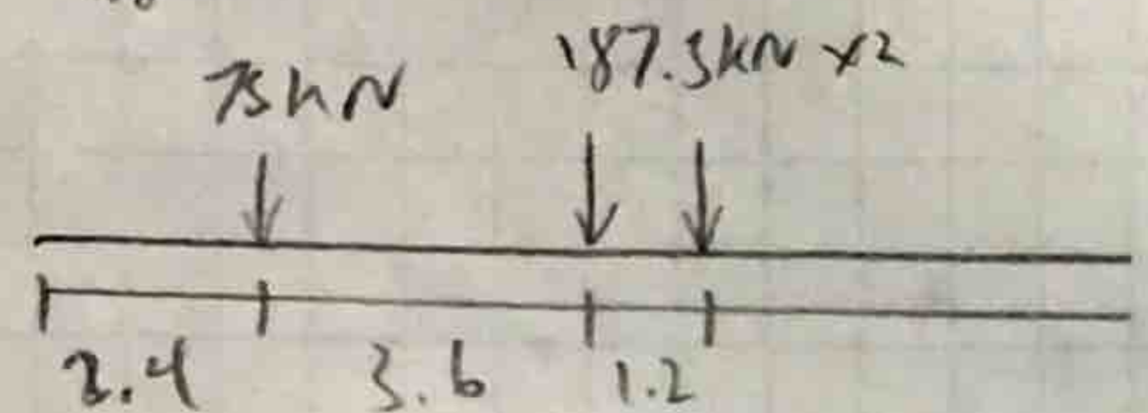
	Shear	Moment
①	380.63 @ 11.4-12	1008 @ 4.8
②	327.5 @ 10.4-12	955 @ 3.8
③	416.25 @ 0-0.6	796.5 @ 8.4
④	275.63 @ 0-0.8	802.12 @ 7.4
⑤	✗ Does not govern	
⑥	✗ Does not govern	
⑦	✗ Does not govern	
⑧	✗ Does not govern	
⑨	✗ Does not govern	
⑩	465	881.34 @ 6.9m

Load Scenarios (cont'd) — Shear | Moment

(11) — Shear: N/A — Moment: 1086.75 @ 5.4



(12) — Shear: N/A — Moment: 1102.5 @ 6.0



Load case (10) governs shear

(12) governs moment

Try CSA 3.8.3.1.2

(10-1) Shear = 408 @ 0 (12-1) Shear = 237 @ 0

Moment = 784 @ 7.9 Moment = 1044 @ 6

∴ Load Case 10 and 11 govern shear and moment at

Shear = 465 kN and moment = 1102.5 kNm

Dead Load

Concrete of bridge itself: Via table 3.3 of CSA

∴ Load from concrete = $24 kN/m^3$

Translate the unit weight to a distributed load

∴ $24 kN/m^3$

✱ Design with live loads to get an idea of thickness

Design Loads

$DL = 14.4\ kN/m$

$M_{LL} = \frac{1102.5 kNm}{12} = 91.88\ kNm/m$ $V_{LL} = 465 KN$

<u>Total shear</u>

$V_f = 1.2 \frac{w_{DL} l_e}{2} + 1.7 V_{LL} = 890 kN$

<u>Total Moment</u>

$l_e = 12000 - 200 = 11600 mm = 11.6 m$

$\therefore M_{DL} = \frac{w_{DL} l_e^2}{12} = 161\ kNm$

$M_f = 1.2 M_{DL} + 1.7 M_{LL} = 350 kNm$

<u>Slab Thickness</u>

$h = \frac{l_e}{20} = \frac{11600}{20} = 580 mm \cong 600 mm$

<u>Effective Depth</u>

Use a cover of 50mm and 25M rebar, $d_b = 25mm$

$d = h - cover - d_b/2 = 538 mm$

<u>Required Flexural reinforcement</u>

$A_s = 0.0015 f'_c b (d - \sqrt{d^2 - \frac{3.85 M_r}{f'_c b}})$ Use $M_r = M_f$

$= 1975\ mm^2/m$

<u>Spacing</u>

$A_b = 500 mm^2$

$s \leq A_b \frac{1000}{A_s} \cong 250 mm$

Check Spacing

$A_s = A_b \frac{1000}{s} = 2000\ mm^2 > 1975\ mm^2$ ✓

Check Reinforcement Ratio

$\rho = \frac{A_s}{bd} = 0.0037 < 0.022$ ✓

Check Minimum Flexural Reinforcement

a) $A_g = bd = 538000\ mm^2$

b) $A_{s,min} = 0.002 A_g = 1076\ mm^2 < A_s = 2000\ mm^2$ ✓

Check Max bar spacing

$s_{max} = \min \begin{Bmatrix} 3h \\ 500 \end{Bmatrix} = \min \begin{Bmatrix} 1800 \\ 500 \end{Bmatrix} = 500mm > 250\ mm$ ✓

Find Moment Resistance of design

a) $a = \frac{\phi_s f_y A_s}{\alpha_1 \phi_c f'_c b} = \frac{680000}{13000} = 52.3\ mm$

b) $M_r = \phi_s f_y A_s (d - a/2) = 348\ kNm \cong 350kNm$ close enough

Check Cracking Parameter

a) $d_s = d_c = h - d = 62mm$

b) $A = s(2d_s) = 31000\ mm^2$

c) $f_s = 0.6 f_y = 240\ MPa$

d) $Z = f_s \sqrt[3]{d_c A} = 29839 > 25000$, Need to decrease bar spacing

Try $s = 150mm$

b-2) $A = s(2d_s) = 18600\ mm^2$

d-2) $Z = f_s \sqrt[3]{d_c A} = 25167 \cong 25000$, close enough

Re-check Reinforcement Ratio

$A_s = A_b \frac{1000}{s} = 3333 mm^2$

$\rho = \frac{A_s}{bd} = 0.0062 < 0.022$ ✓

Shrinkage and Temperature

a) $A_{s,min} = 1076 mm^2$

b) $S_{max} = \min \begin{Bmatrix} 5h \\ 500 \end{Bmatrix} = \begin{Bmatrix} 3000 \\ 500 \end{Bmatrix} = 500 mm$

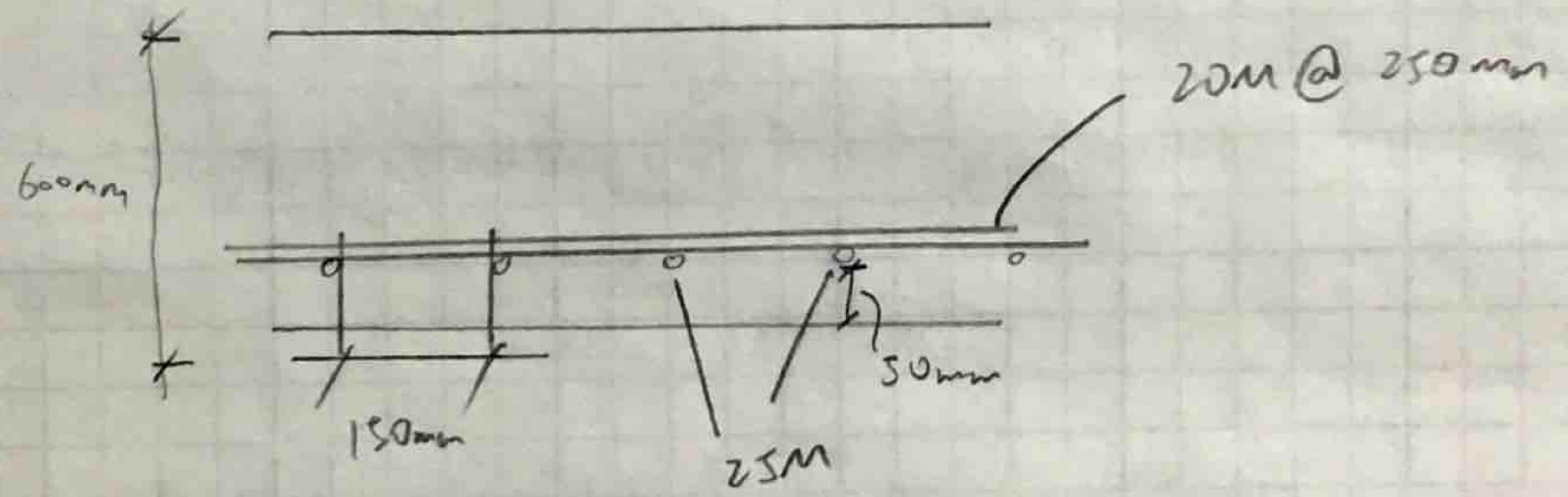
c) $A_b = 300 mm^2$ (20M)

$s \leq A_b \frac{1000}{A_{s,min}}$

$\cong 250 mm$

d) $A_s = A_b \, 1000/s = 1200 mm^2 > 1071 mm^2$ ✓

Final Spec



67-25M

V_f from Page 4 - V2 = 890 kN

Effective depth, d = 538 mm

Effective Shear Depth

$$d_v = \max\begin{Bmatrix} 0.9d \\ 0.72h \end{Bmatrix} = \max\begin{Bmatrix} 484 \\ 432 \end{Bmatrix} = 484\,mm$$

Concrete Shear Resistance

$$V_{cr} \quad \beta = \frac{230}{1000+d_v} = 0.155$$

$$V_c = \phi_c \lambda \beta \sqrt{f'_c}\, b_w d_v$$

$$= 243.8\,kN$$

Since $V_f > V_c$, we will need shear reinforcement

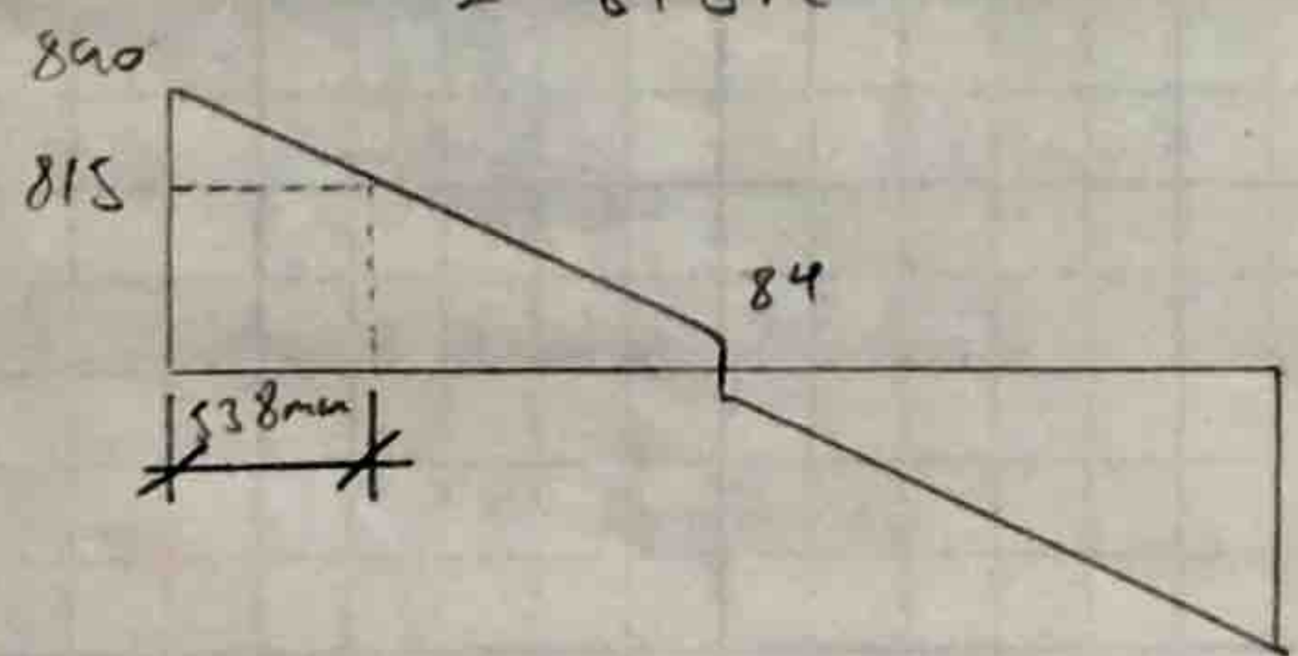
Shear Distribution

$$V_{f,mid} = \frac{1.5\,LL\left(\frac{l_e}{2}\right)}{4} = 84\,kN$$

$$V_{sr}\ LL = 465\,kN/12\,m = 38.75\,kN/m$$

$$V_{f@d_v} = V_{f,mid} + \left(\frac{\frac{l_e}{2} - d_v}{\frac{l_e}{2}}\right)(V_f - V_{f,mid})$$

$$= 815\,kN$$



Required Steel Resistance

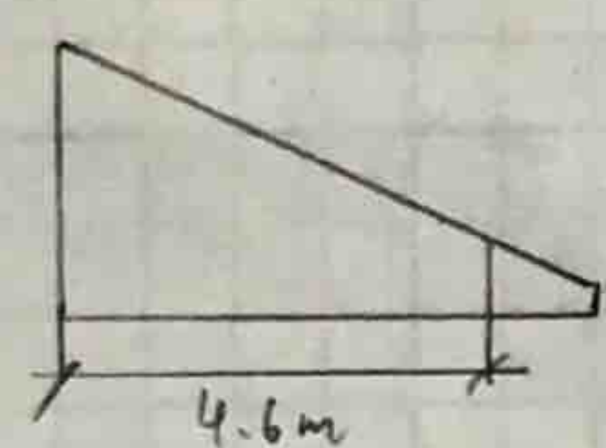
$V_{s@d_v} - V_c = V_s = 571\ kN$

Let $V_{s@x} = 244\ kN$

$= V_{f,mid} + \left(\frac{\frac{l_n}{2} - x}{\frac{l_n}{2}}\right)(V_f - V_{f,mid})$

$= 84\ kN + \frac{5.8m - x}{5.8m}(806\ kN)$

$x = 4.6\ m$



we want two regions ∴ we find a second V_c using $\beta = 0.18$

$V_c = \phi_c \lambda \beta \sqrt{f'_c}\, b_w d_v = 315\ kN$

Required Stirrup Spacing (Minimum)

Use 20M stirrups

$A_v = (2\ legs)(A_b)$

$= 600\ mm^2$

$s = \frac{\phi_s A_v f_y d_v \cot\theta}{V_s} = 250\ mm$

Check Requirements

① $s = \frac{A_v f_y}{0.06 \sqrt{f'_c}\, b_w} = 800\ mm$

② $Max\ V_r = 0.25 \phi_c f'_c b_w d_v = 1966\ kN$

Since $V_f < \frac{1}{2} Max\ V_r$

$s \leq \begin{Bmatrix} 600 \\ 0.7 d_v \end{Bmatrix} = \begin{Bmatrix} 600 \\ 339 \end{Bmatrix}$

③ Use min of 800, 600, 339, 250 $= S = 250\ mm$

Check strength

$$V_s = \frac{\phi_s A_v f_y d_v \cot\theta}{s} = 565 \text{ kN}$$

$V_r = V_c + V_s = 244 + 565 = 809 \text{ kN} < 890 \text{ kN}$ ✗

we will use as Region I reinforcement

Use 25M rebar

Full Reinforcement Location

$V_{s@x_2} = 809 \text{kN}$

$$V_{s@x_2} = V_{f,mid} + \left(\frac{\frac{l_e}{2} - x_2}{\frac{l_e}{2}}\right)(V_f - V_{f,mid})$$

$= 0.76 \text{ m}$

Full Reinforcement Spacing

$V_s \geq V_f - V_c = 890 -$

$$V_f = 1.2 \frac{w_{DL} l_e}{2} + 1.7 \times (465 \text{kN}/40 \text{m})$$

$= 120 \text{kN} < V_c$ ✓
244kN

Wall Height

We will use a $h = 3m$

Also, we analyze a unit wall strip, $b = 1m = 1000mm$

Factored Soil Pressure

$\gamma = 19 \ kN/m^3$
$k_o = 0.5$

$P_{o,f} = P_o(1.25) = h\gamma k_o(1.25) = 36 \ kPa$

Factored Bending Moment

$w_f = \frac{P_{o,f}}{2} = 18 \ kPa$

$M_f = \frac{w_f(h)^2}{8} = 20.3 \ kNm/m$

Factored Shear force

$V_f = \frac{P_{o,f} \times h}{3} = 36 \ kN/m$

Wall Thickness

$t = \max\left\{ \begin{matrix} h/25 \\ 190 \end{matrix} \right\} = \max\left\{ \begin{matrix} 120 \\ 190 \end{matrix} \right\} = 190mm$, use $200mm$

Effective Depth

Use 15M rebar, $d_b = 15mm$ and 40 mm cover

$d = t - cover - d_b/2 = 130 \ mm$

Required Flexural Reinforcement

$M_r = M_f = 20.3 \ kNm/m$

$A_s = 0.0015 f'_c b \left(d - \sqrt{d^2 - \frac{3.85 M_r}{f'_c b}} \right)$

$= 405 \ mm^2/m$

Spacing

$S \leq A_b \frac{1000}{A_s} = 494 \ mm \approx 300mm$

Check Spacing

$S_{max} = \min\begin{Bmatrix} 3t \\ 500 \end{Bmatrix} = \min\begin{Bmatrix} 600 \\ 500 \end{Bmatrix} = 500mm = S$ ✓

Check Reinforcement Ratio

$\rho = \frac{A_s}{bd} = 0.0027 < 0.022$ ✓

Check Minimum reinforcement

$A_g = L t = 200000 \ mm^2$

$A_{v,min} = 0.0015 A_g = 300mm^2 < 405 mm^2/m$ ✓

Shear Design

$V_f = 36 kN/m$

Effective Shear Depth

$d_v = \max\begin{Bmatrix} 0.9d \\ 0.72t \end{Bmatrix} = \max\begin{Bmatrix} 135 \\ 144 \end{Bmatrix} = 144m$

Concrete Shear Resistance

$\beta = \frac{230}{1000+d_v} = 0.20$

$V_c = \phi_c \lambda \beta \sqrt{f'_c} \, b_w d_v = 93.6 kN/m > V_f = 36 kN/m$

but we will include minimum

Minimum horizontal reinforcement

$A_g = 200000 mm^2$

$A_{s,min} = 0.002 A_g = 400 mm^2/m$

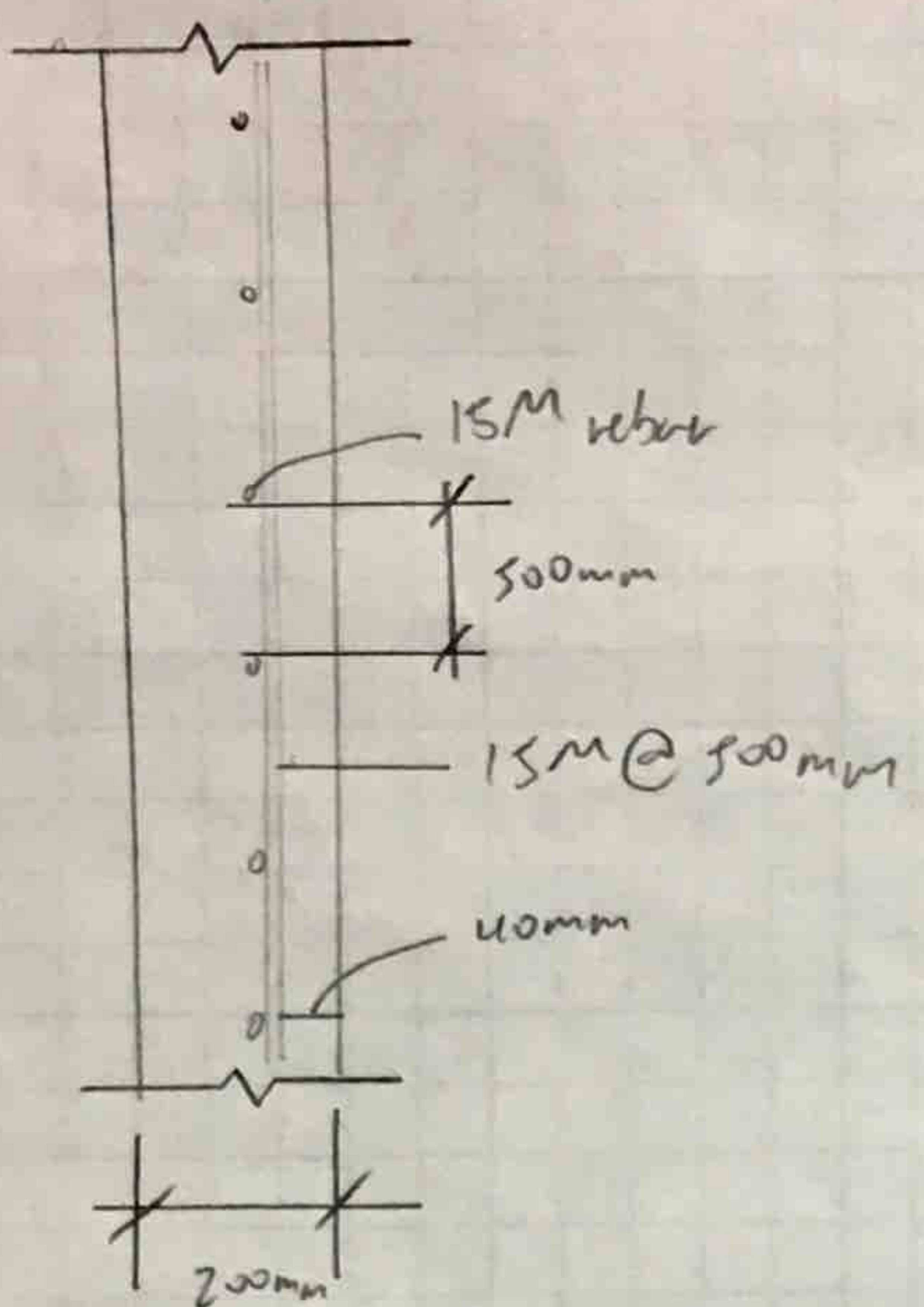
Using 15M bars, $A_b = 200mm^2$

$S \leq A_b \frac{1000}{A_s} = 500mm$

Check spacing

$S_{max} = \min\begin{Bmatrix} 3t \\ 500 \end{Bmatrix} = 300mm$

V2



From SkyCiv,

$P_{LL} = 443\,kN / 40\,m = 11\,kN/m$

$P_{DL} = 86.4\,kN/m$

From basement wall,

$t = 0.2\,m$

Footing Width

$q_{all} = 100\,kPa$

$l \geq \frac{P_s}{b \times q_{all}} = \frac{P_D + P_{LL}}{b \times q_{all}} = 0.974\,m \cong 1\,m$

Factored Soil Pressure

$A = l \times b = 1\,m^2$

$q_f = \frac{P_f}{A} = \frac{1.25 P_{DL} + 1.5 P_{LL}}{A} = 124.5\,kPa \cong 130\,kPa$

Footing Thickness

Concrete cover = 75mm

Try thickness, h = 250mm

Use 15M, $d_b = 15\,mm$

$d = h - cover - \frac{d_b}{2} = 165\,mm$

☆ $V_f = q_f \times b \times \left(\frac{l-t}{2} - d_v\right) = 28.6\,kN/m$

$d_v = \max\begin{Bmatrix} 0.9d \\ 0.72h \end{Bmatrix} = \max\begin{Bmatrix} 117 \\ 180 \end{Bmatrix} = 180\,mm = 0.18\,m$

Using a $\beta = 0.21$ because $h = 250 < 350$

$V_c = \phi_c \lambda \beta \sqrt{f'_c}\, b_w d_v = 122.85\,kN/m > V_f$ ✓

Required Flexural Reinforcement

$M_f = q_f \left(\frac{l-t}{2}\right)\left(\frac{l-t}{4}\right) \times b = 10.4\ kNm/m$

Let $M_r = M_f = 10.4\ kNm/m$

$A_s = 0.0015 f'_c b \left(d - \sqrt{d^2 - \frac{3.85 M_r}{f'_c b}} \right) = 169\ mm^2/m$

Check minimum flexural reinforcement

$A_g = h \times b = 250\,000\ mm^2$

$A_{s,min} = 0.002 A_g = 500\ mm^2/m$

$\therefore$ minimum governs $A_s = 500\ mm^2/m$

Spacing

$A_b = 200\ mm^2$

$s \leq A_b \frac{1000}{A_s} = 400\ mm$

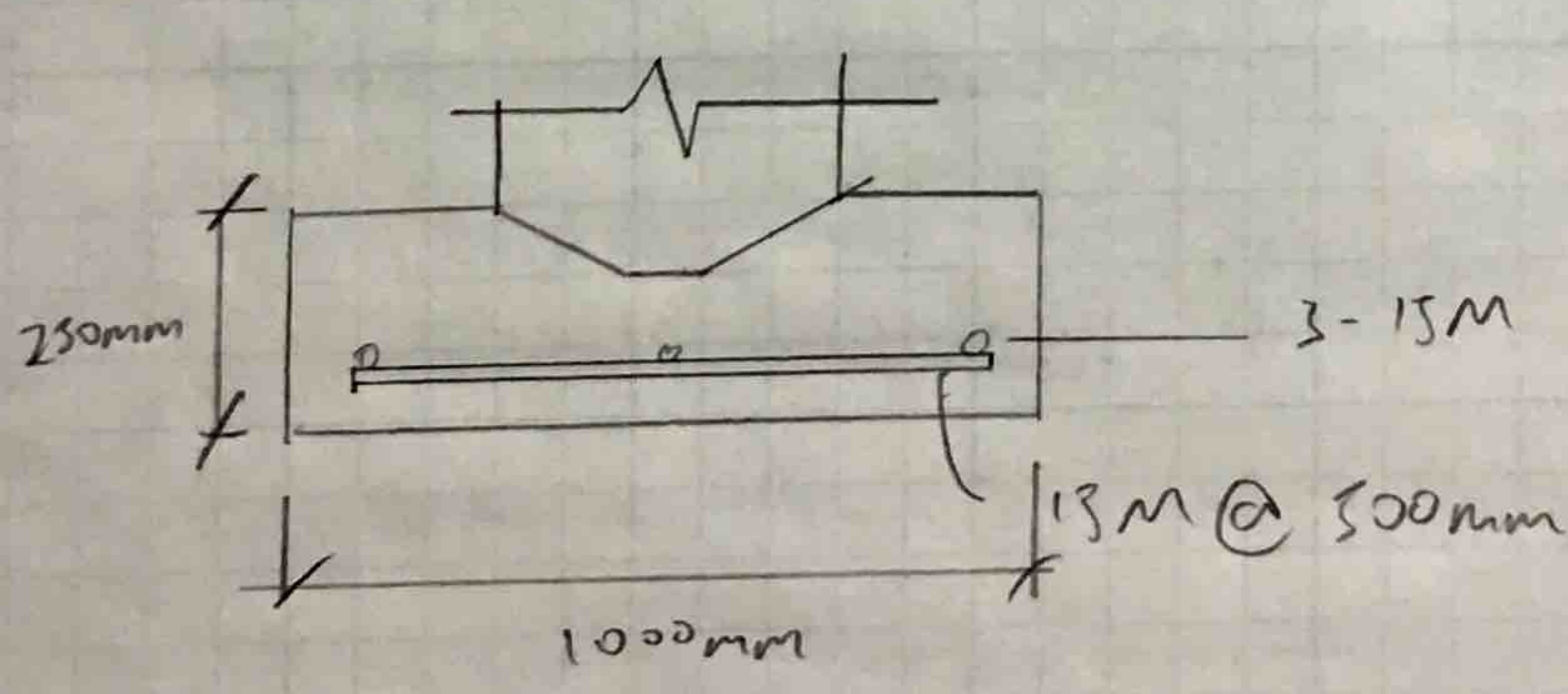
Longitudinal reinforcement

$A_g = h \times l = 250\,000\ mm^2$

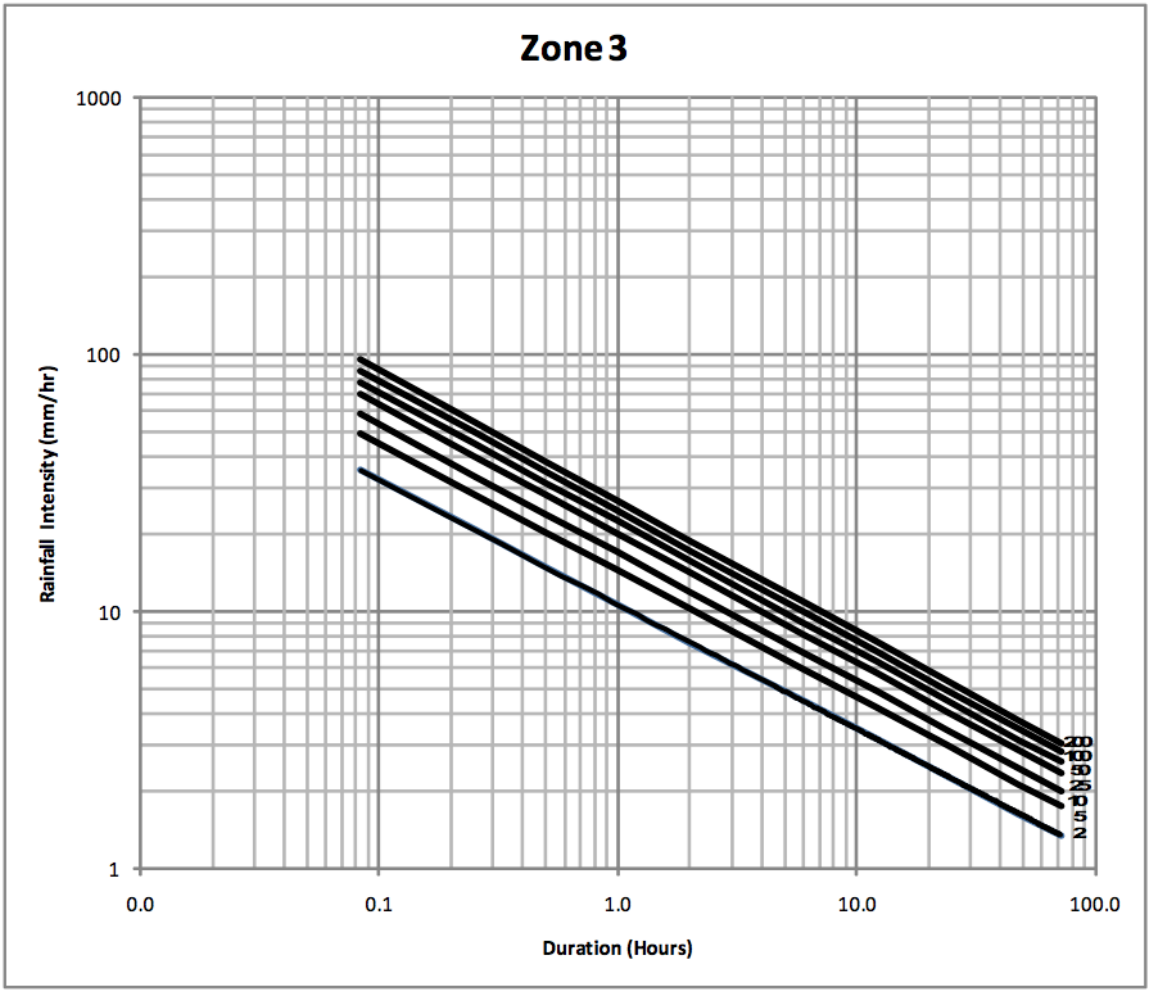
$A_{s,min} = 500\ mm^2$

Use 3-15M bars

$A_s = 3 \times 200\ mm^2 = 600\ mm^2$



Appendix E: Drainage



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 E - 1 - Zone 3 IDF Curve for Metro Vancouver (BCG Engineering, 2012)

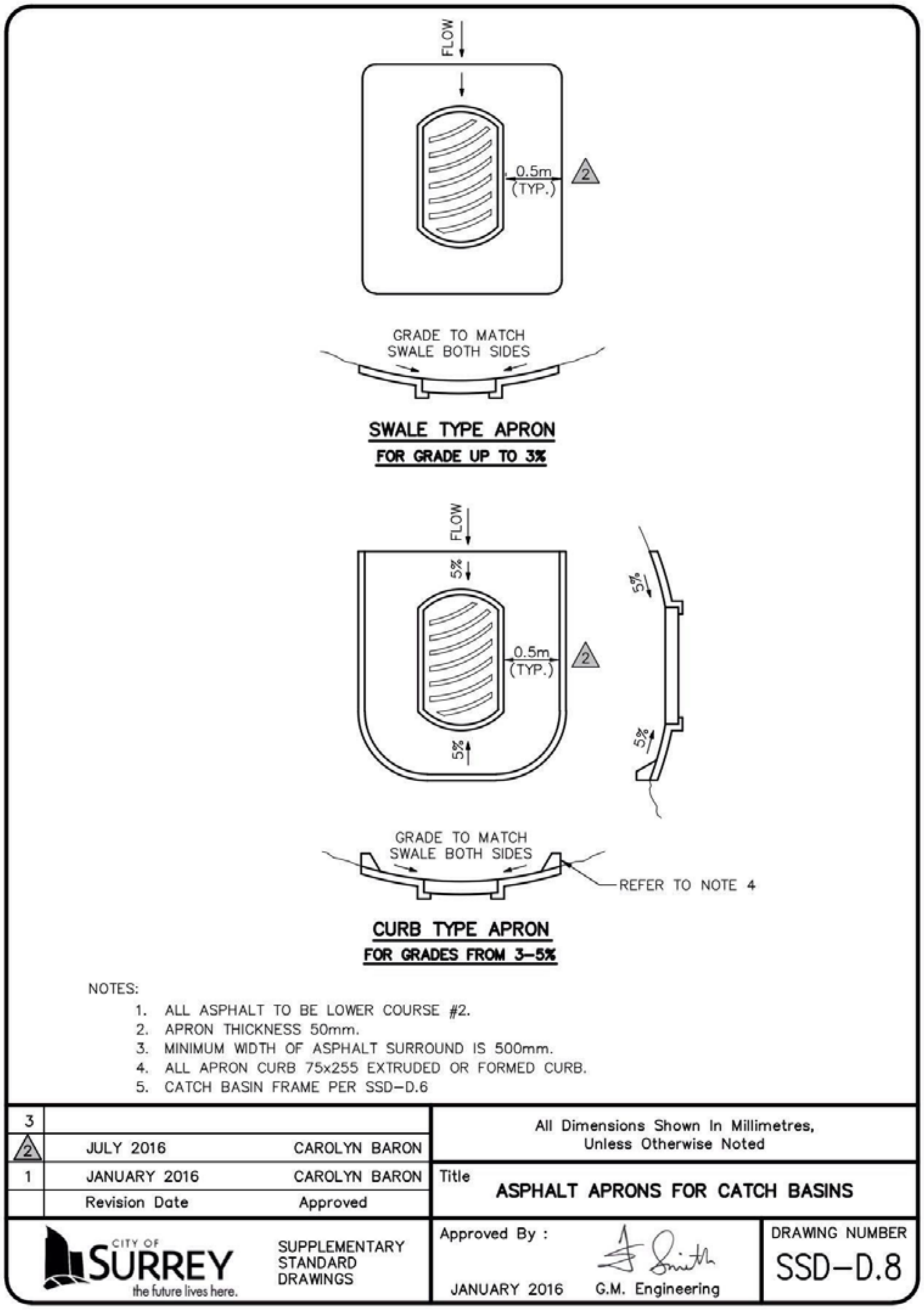


Figure E - 2 - Asphalt Aprons For Catch Basins (Supplementary Standard Drawings, 2016)

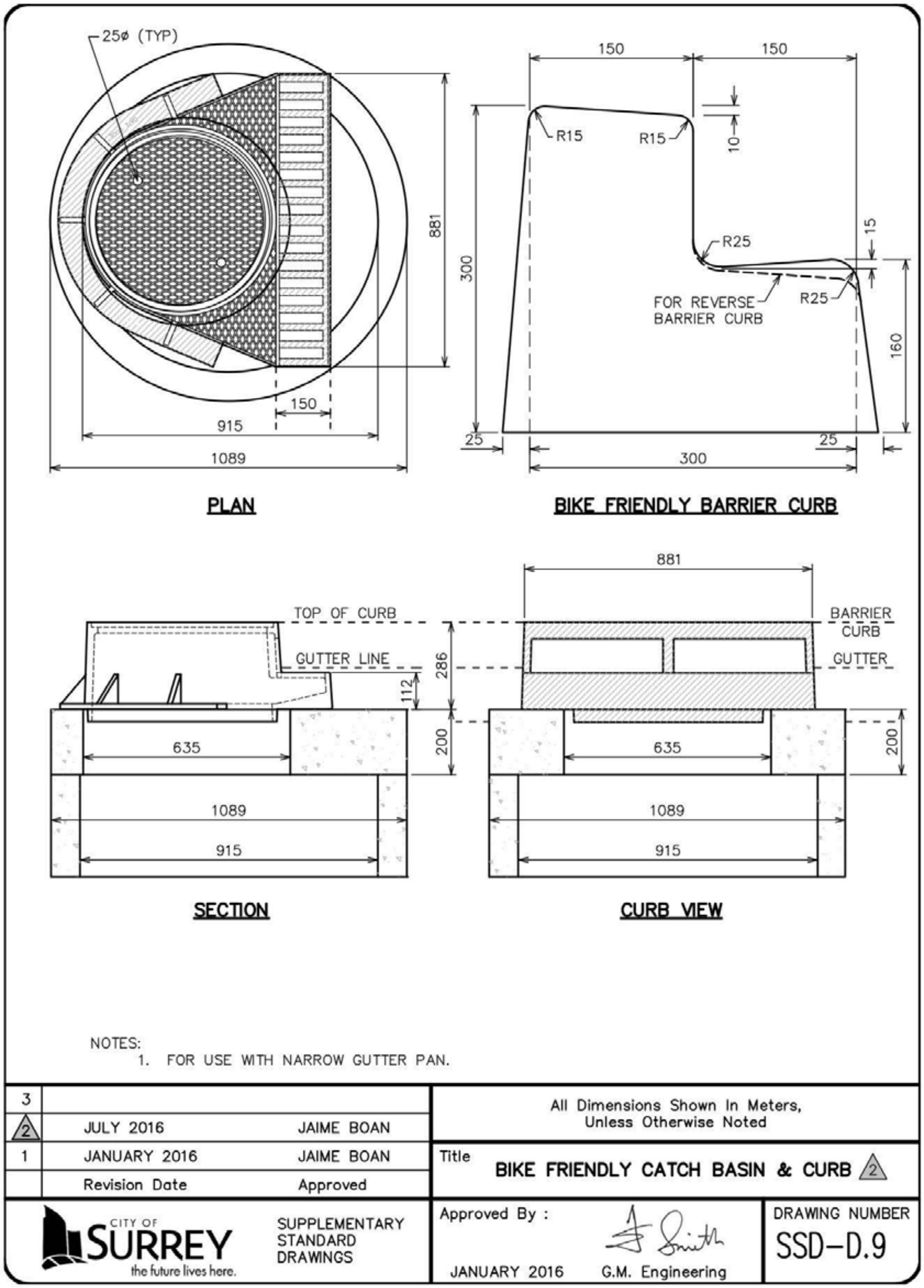


Figure E - 3 - Bike Friendly Catch Basin & Curb (Supplementary Standard Drawings, 2016)

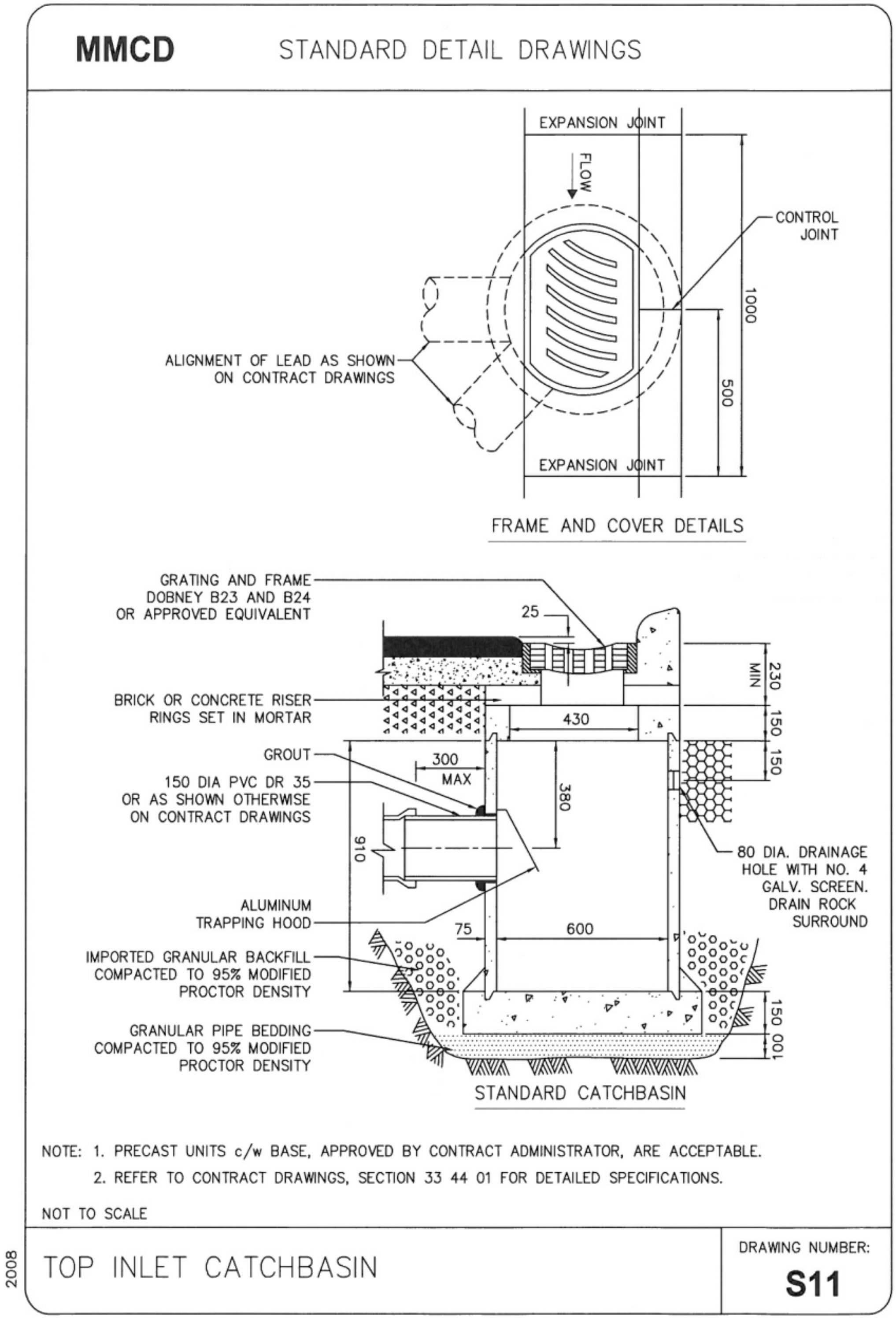


Figure E - 4 - Top Inlet Catch Basin (MMCD, 2009)

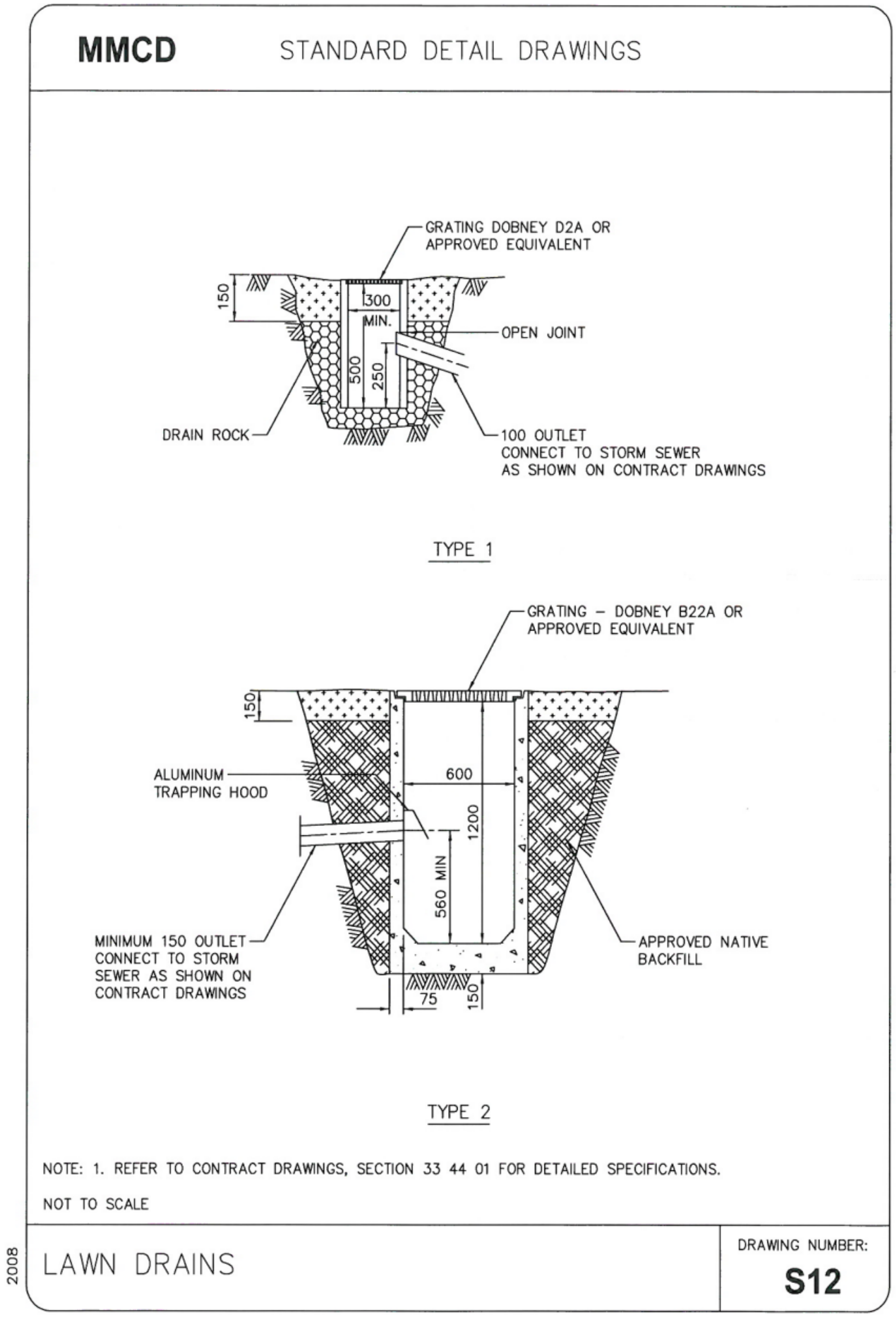


Figure E - 5 - Lawn Drains Design (MMCD, 2009)

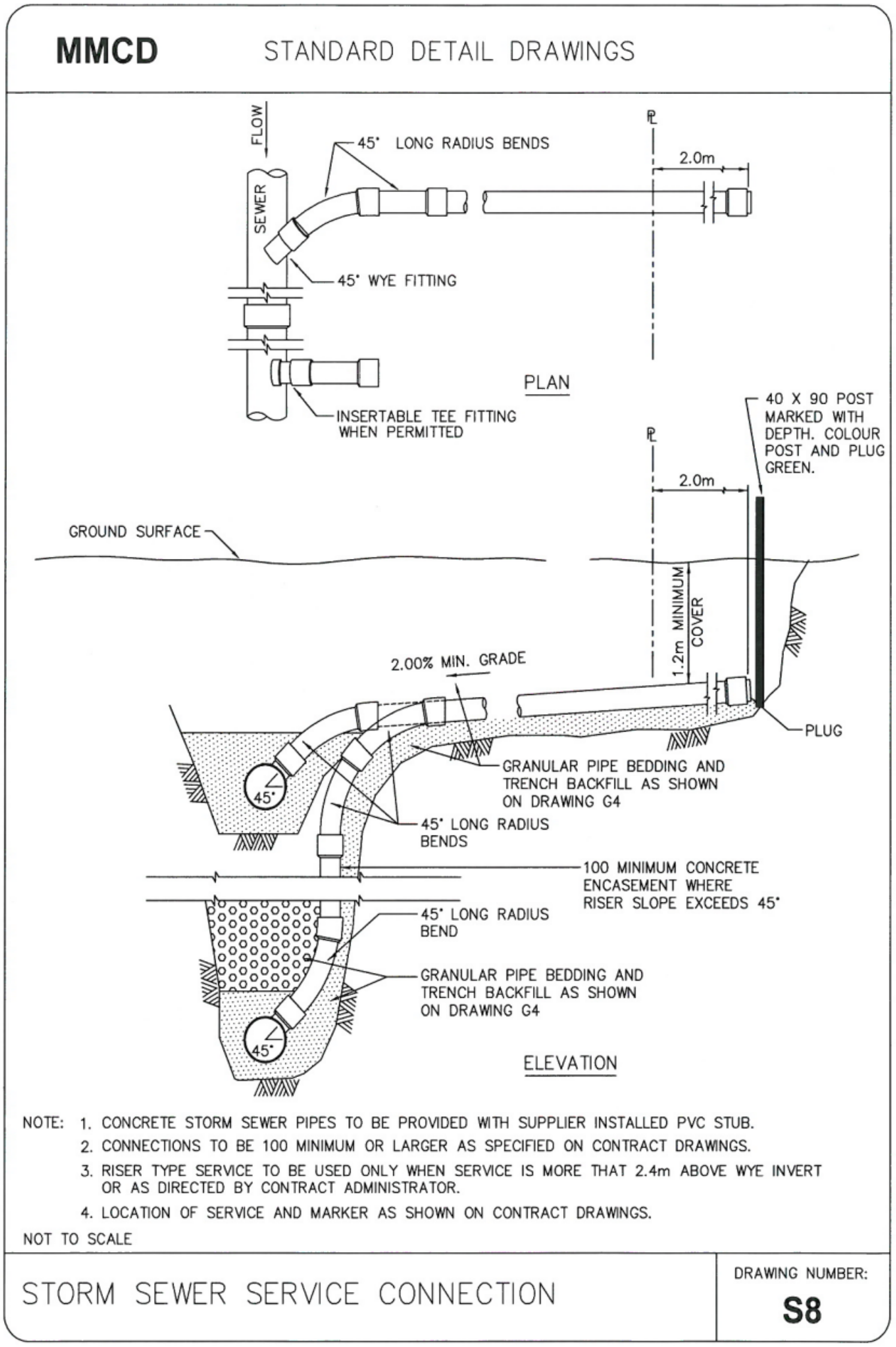


Figure E - 6 - Storm Sewer Service Connection (MMCD, 2009)

Appendix F: Construction Planning

Figure F - 1 - Construction Site Plan

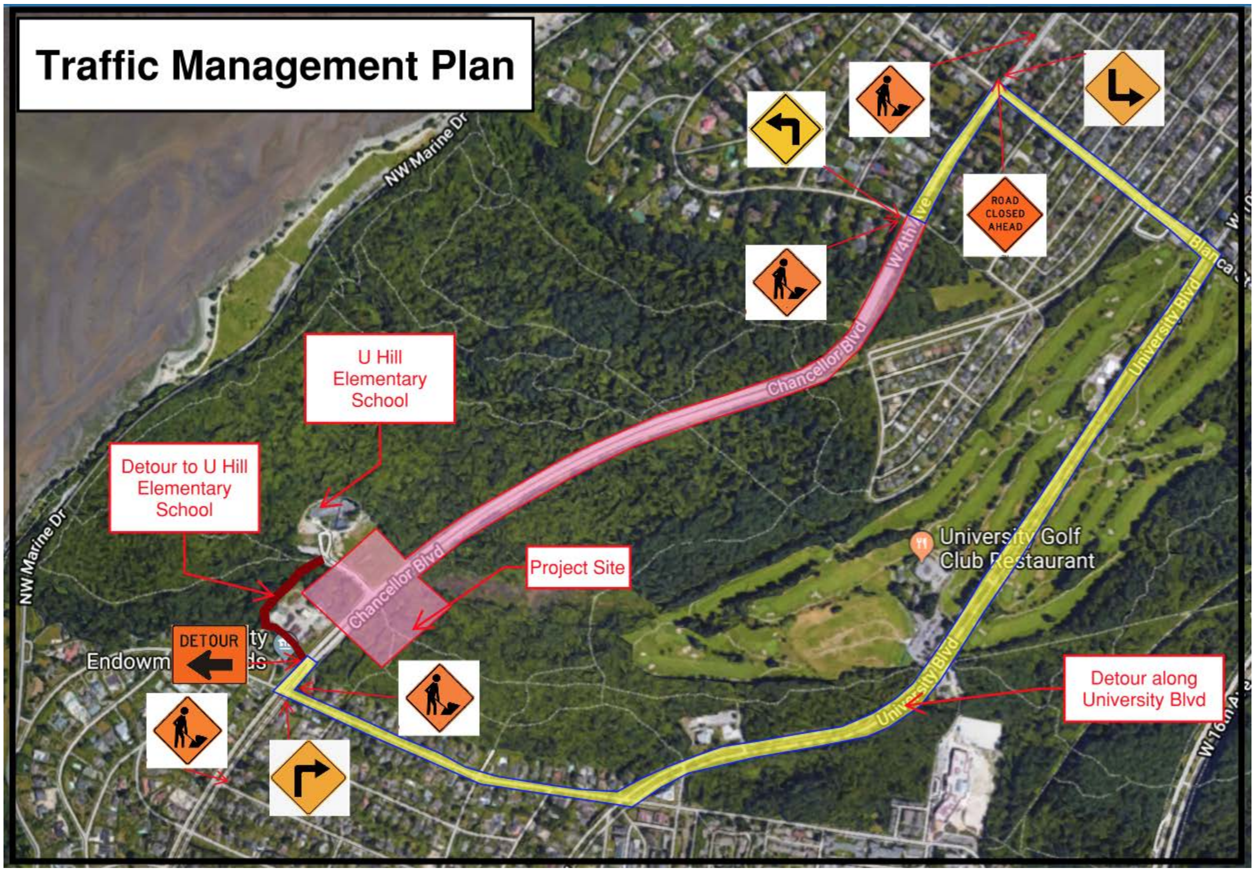


Figure F - 2 - Traffic Management Plan

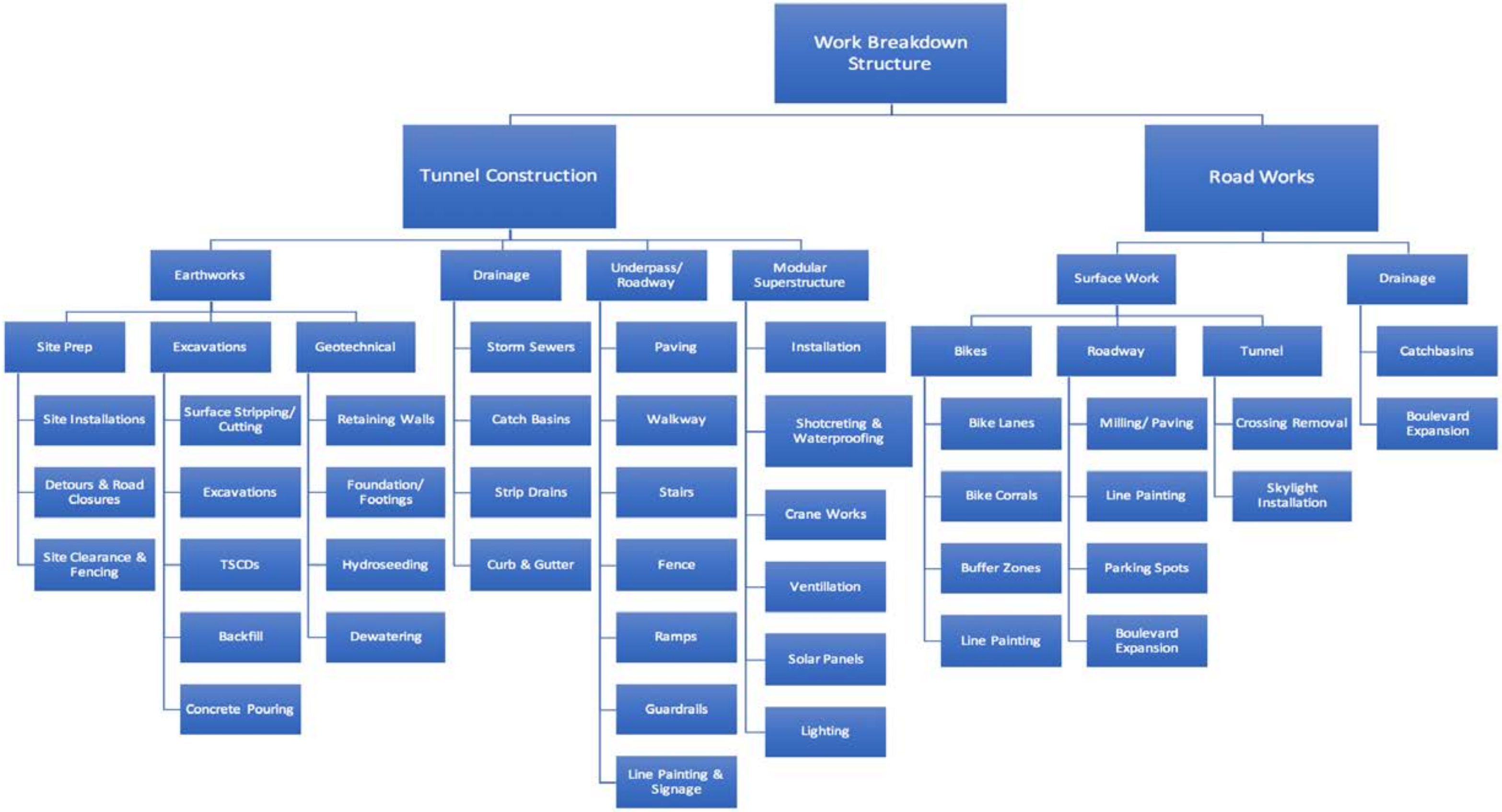


Figure F - 3 - Work Breakdown Structure

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Appendix G: Cost Estimate

ID	Description	Units	Quantity	Quantity (Rounded)	Year	Unit Price	Cost	Costs Scaled to 2018	Notes
	Inflation Rate	2%							
General									
1.0	Project Management							$ 206,633.94	5% of Total Project Estimate
1.1	Planning							$ 37,914.49	1% of Construction Estimate
1.2	Design							$ 303,315.88	8% Construction Base Estimate
							Sub-Total	**$ 547,864.31**	
Road Infrastructure									
1.0	Concrete Sidewalks, Medians, Landing Pads	m^2	2904	3000	2017	$ 75.00	$ 225,000.00	$ 229,500.00	
1.1	Concrete Curb and Gutter	l.m	391.58	400	2014	$ 56.60	$ 22,640.00	$ 24,506.26	
1.2	Asphalt Roadway - 50mm	m^2	13739	13740	2013	$ 34.01	$ 467,360.75	$ 516,004.03	Areas of milled existing asphalt, assume 80% of total roadway
1.3	Asphalt Roadway - 100mm	m^2	1355.5	1400	2013	$ 68.03	$ 95,240.91	$ 105,153.66	Multi-use Path
1.4	Asphalt Roadway - 240mm	m^2	3434.76	3440	2013	$ 163.27	$ 561,649.25	$ 620,106.16	Assume 20% of total roadway is new
1.5	Granular Base - 200mm	m^2	2323.2	2330	2014	$ 13.68	$ 31,874.40	$ 34,501.88	
1.6	Granular Base - 350mm	m^2	4790.26	4800	2015	$ 23.94	$ 114,912.00	$ 121,945.53	
1.7	Granular Sub-base - 300mm	m^2	4790.26	4800	2014	$ 25.20	$ 120,960.00	$ 130,930.99	
1.8	Boulevard	m^2	9194	9200	2014	$ 12.00	$ 110,400.00	$ 119,500.51	Includes supply and labour
1.9	Boulevard Curb	l.m	3532.81	3600	2014	$ 56.60	$ 203,760.00	$ 220,556.38	
1.10	50mm Milling	m^2	13739	13740	2013	$ 7.06	$ 97,012.73	$ 107,109.89	Where proposed asphalt roadway overlaps with existing roadw
1.11	Painted - 100mm Wide Line (Solid White)	l.m	6041.6	6050	2017	$ 4.00	$ 24,200.00	$ 24,684.00	
1.12	Painted - 100mm Wide Line (Dashed White)	l.m	258.16	260	2017	$ 2.00	$ 520.00	$ 530.40	
1.13	Removal - Asphalt Roadway	m^2	3434.76	3440	2014	$ 21.00	$ 72,240.00	$ 78,194.90	
1.14	Removal - Boulevard	m^2	1355.5	1360	2014	$ 40.33	$ 54,853.33	$ 59,375.01	550mm Stripped (150mm Boulevard + 200mm Base + 200mm S
1.15	Removal - Concrete Sidewalk	m^2	2747.81	2750	2014	$ 12.50	$ 34,375.00	$ 37,208.61	
1.16	Removal - Concrete Curb and Gutter	l.m	483.19	490	2014	$ 9.21	$ 4,512.90	$ 4,884.91	
1.17	Removal - Concrete Barrier	L.S	1	1	2017	$ 20,000.00	$ 20,000.00	$ 20,400.00	Lump sum cost to remove concrete centreline barrier along Cha
							Sub-Total	**$ 2,455,093.12**	
Utilities									
2.0	Streetlights	Ea.	35	35	2013	5000	175000	$ 193,214.14	200000 continuous / 1000m with 50m spacing
2.1	Grated Strip Drains	l.m	150	150	2017	14	2100	$ 2,142.00	
2.2	Catch Basin	Ea.	30	30	2014	2600	78000	$ 84,429.71	Pre-cast Catch Basin every 40m
2.3	Catch Basin - Leads	l.m	160	160	2014	485	77600	$ 83,996.74	250mm Catch Basin Lead
2.4	Storm Sewers	l.m	120	120	2014	376.8	45216	$ 48,943.25	375mm Storm Sewer
							Sub-Total	**$ 412,725.84**	
Structural Infrastructure									
3.0	Retaining Walls (Concrete)	m^2	390	390	2013	$ 1,100.00	$ 429,000.00	$ 473,650.66	
3.1	Asphalt Roadway - 100mm	m^2	165	170	2013	$ 68.03	$ 11,564.97	$ 12,768.66	
3.2	Railing	l.m	50	50	2013	$ 250.00	$ 12,500.00	$ 13,801.01	
3.3	Steel Pipe Fencing / Railing	l.m	50	50	2013	$ 250.00	$ 12,500.00	$ 13,801.01	
3.4	Reinforced Concrete Bridge	m^3	1102.5	1200	2013	$ 200.00	$ 240,000.00	$ 264,979.39	
3.5	Rebar	l.m	2600	2600	2017	$ 2.46	$ 6,396.00	$ 6,523.92	
3.6	Gutter Pan	l.m	60	60	2013	$ 25.00	$ 1,500.00	$ 1,656.12	
3.7	Ramp - Asphalt Cover 100mm	m^2	900	900	2013	$ 68.03	$ 61,226.30	$ 67,598.78	
3.8	Ramp - Concrete Base	m^2	900	900	2017	$ 75.00	$ 67,500.00	$ 68,850.00	
							Sub-Total	**$ 923,629.56**	
							Total	**$ 4,339,312.82**	
							Contingency (20%)	**$ 867,862.56**	
							Total (Rounded)	**$ 5,208,000.00**	

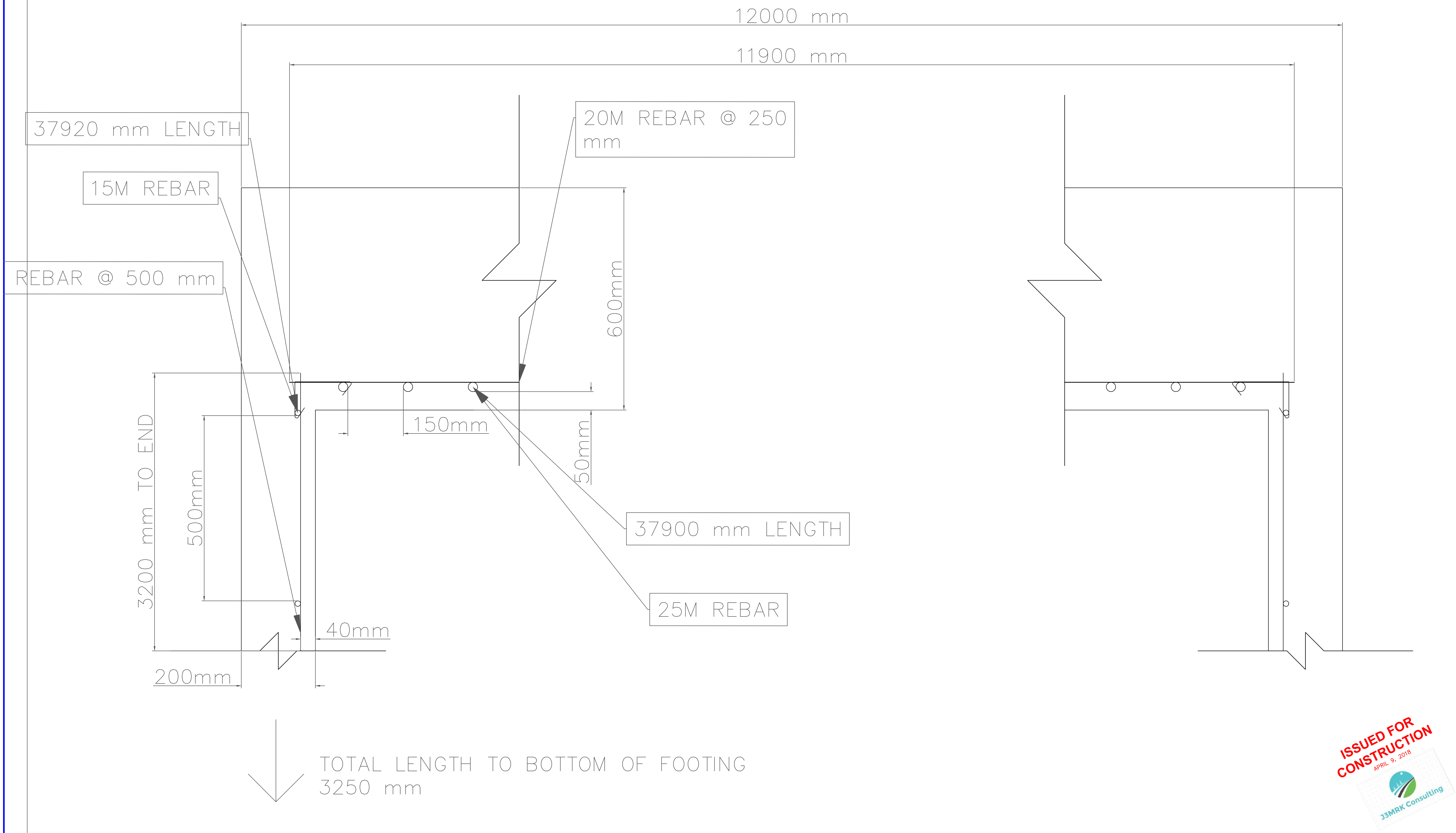
Figure G - 1 - Cost Estimate

Appendix H: Maintenance Plan

Section	Existing?	Component	Description	Cost ($)	Year to start	Recurring every ? years
Structural	No	Underpass	Inspections	600	2020	2
Structural	No	Underpass	Concrete Surfacing	30	2018	1
Structural	No	Underpass	Asphalt Resealing	600	2031	1
Transportation	Yes	Roadway	Resealing	20400	2031	1
Transportation	Yes	Multi-use pathway	Repairs	5000	2031	1
Transportation	No	Boulevard and median	Maintenance	5600	2018	1
Utilities	No	Lighting	light bulbs	180000	2043	25
Utilities	No	Porous asphalt and pervious concrete for the bike lanes and the sidewalk	Sweeping and Vacuuming	10000	2018	1
Utilities	No	Lighting	Painting	32310	2023	5
Utilities	No	Drainage	Mains inspections and cleaning	2000	2023	5
Utilities	No	Drainage	French drain cleaning	800	2018	3
			Total FW	18251539	FW	
			Total Pw	5330030	PW	
			Total Annuity	123671	Annuity	

Figure H - 1 - Maintenance Plan

Appendix I: Design Drawing Package



REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
1. ALL HOOKS INDICATED IN DRAWING SHOULD BE USED AS 135 DEGREE ANGLES
2. ENSURE ALL REBAR CAGES ARE SET TO PROPER HEIGHTS AND CONCRETE COVERS
3. ALL SPACING WILL CONTINUE AS INDICATED FOR ALL TYPICAL SPACINGS
4. ALL TYPICAL REBAR LENGTHS ARE INDICATED IN THE DRAWINGS
5. ALL REBAR REPRESENTED BY LINES ARE THE CENTER LINES OF THE INDICATED REBAR SIZE

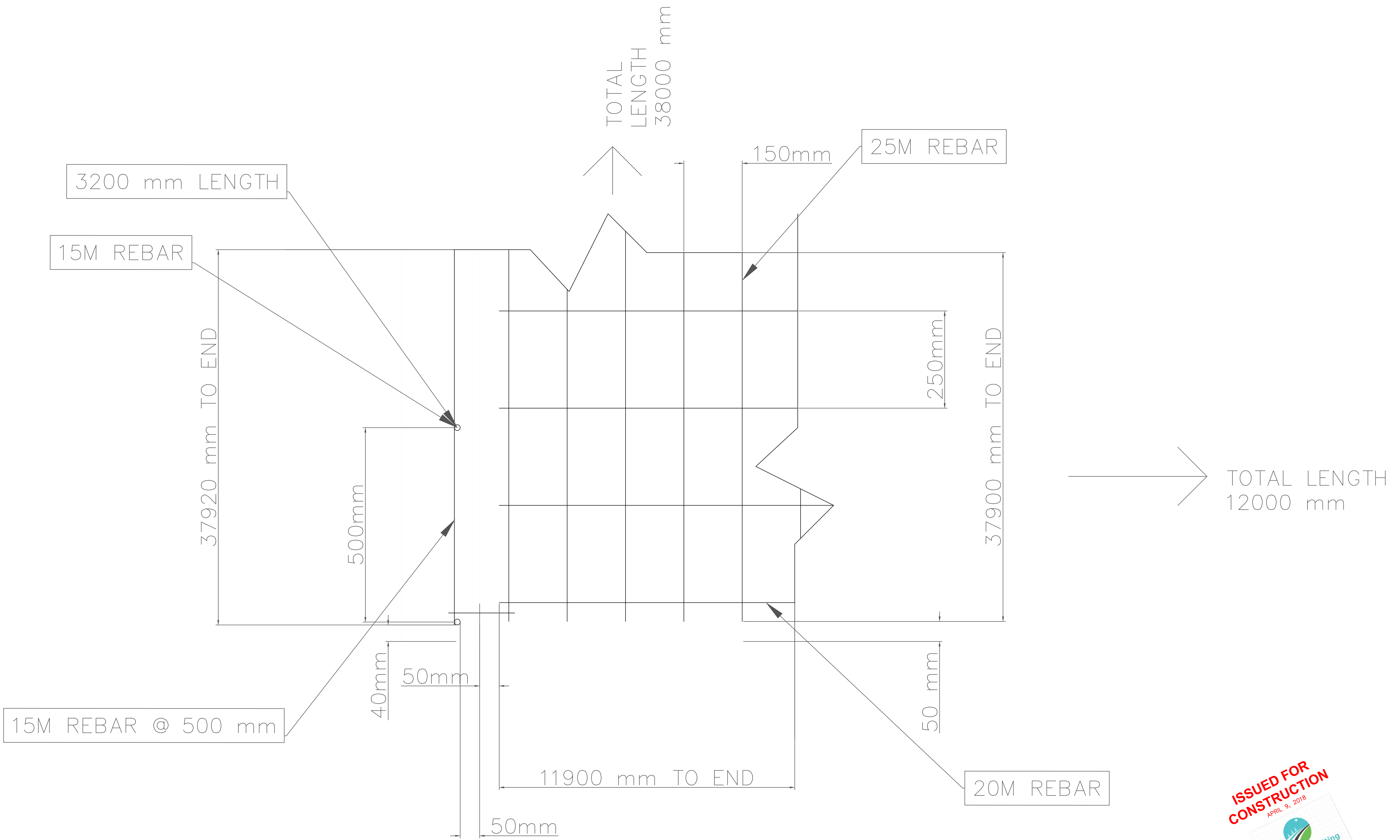
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
SLAB AND WALL JOINT SECTION VIEW

SCALE:1:5
DESIGNED JL
DRAWN JL
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **R-01**
REV. 1



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SLAB PLAN VIEW

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DWG. NO. **R-02**
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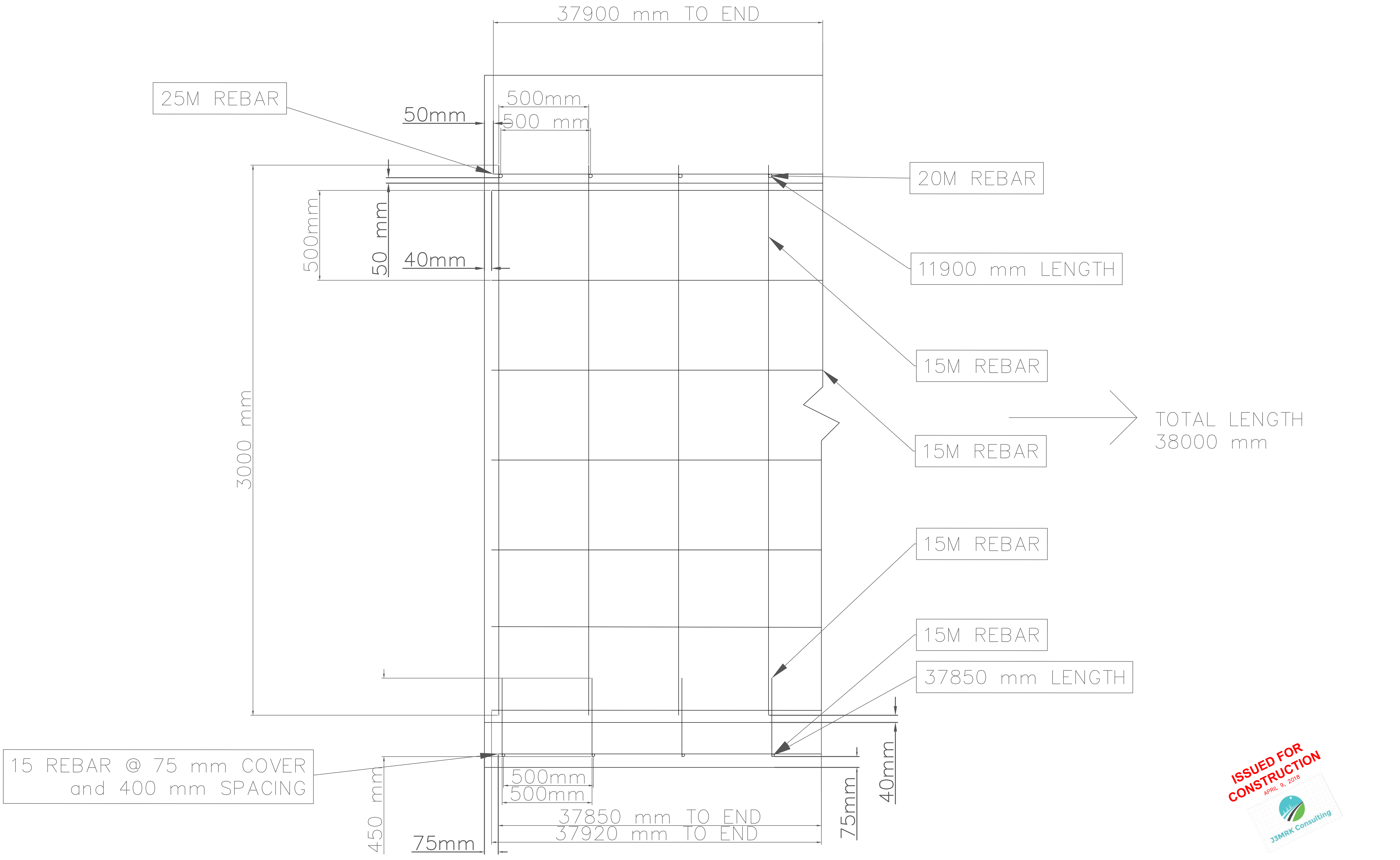

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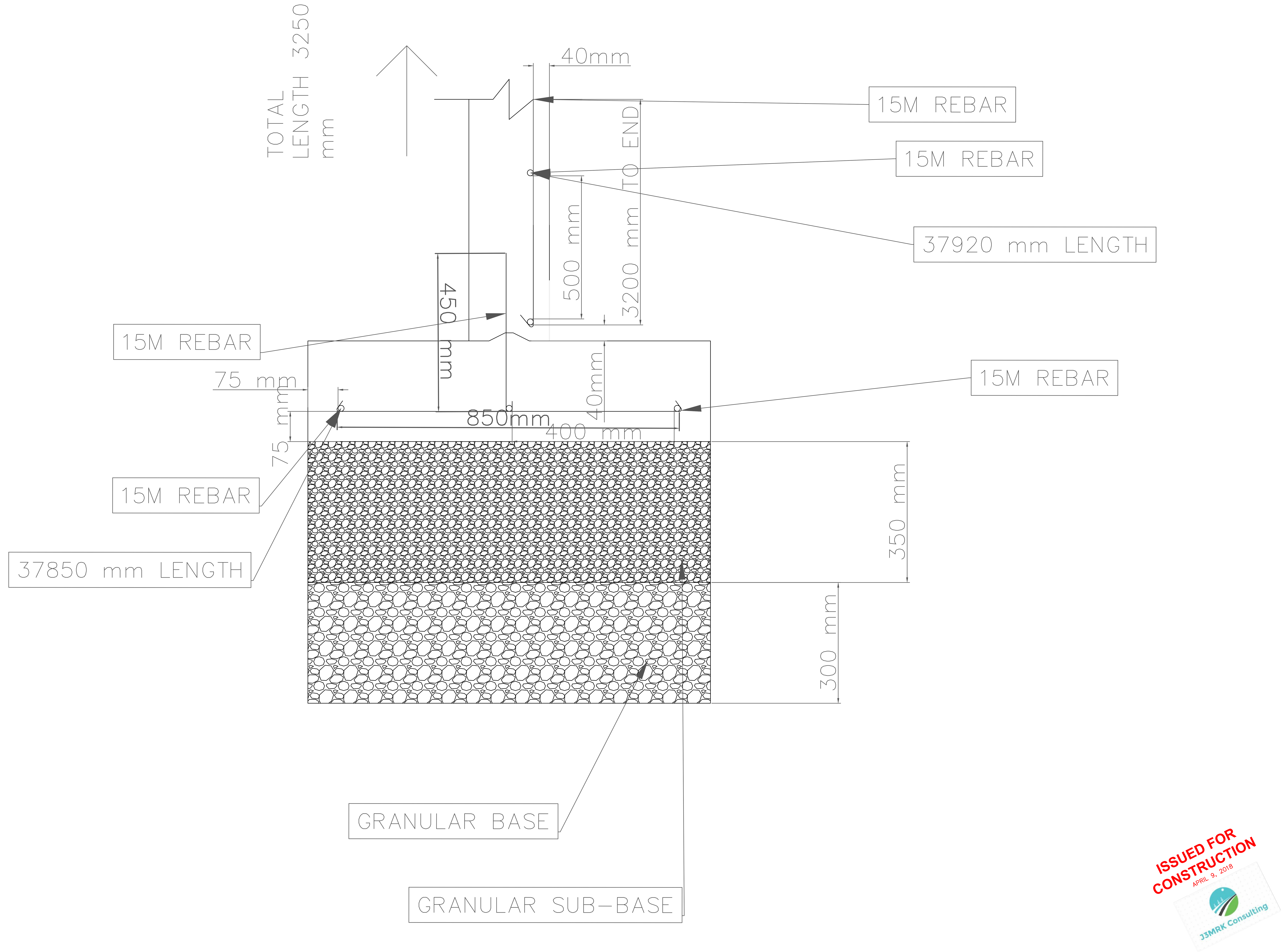
TITLE CHANCELLOR BOULEVARD REDESIGN
SLAB, WALL, FOOTING SIDE VIEW

SCALE:1:10
DESIGNED JL
DRAWN JL
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-03
REV. 1



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NOTES
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TITLE **CHANCELLOR BOULEVARD REDESIGN**
WALL AND FOOTING JOINT SECTION VIEW

SCALE:1:5
DESIGNED JL
DRAWN JL
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **R-04**
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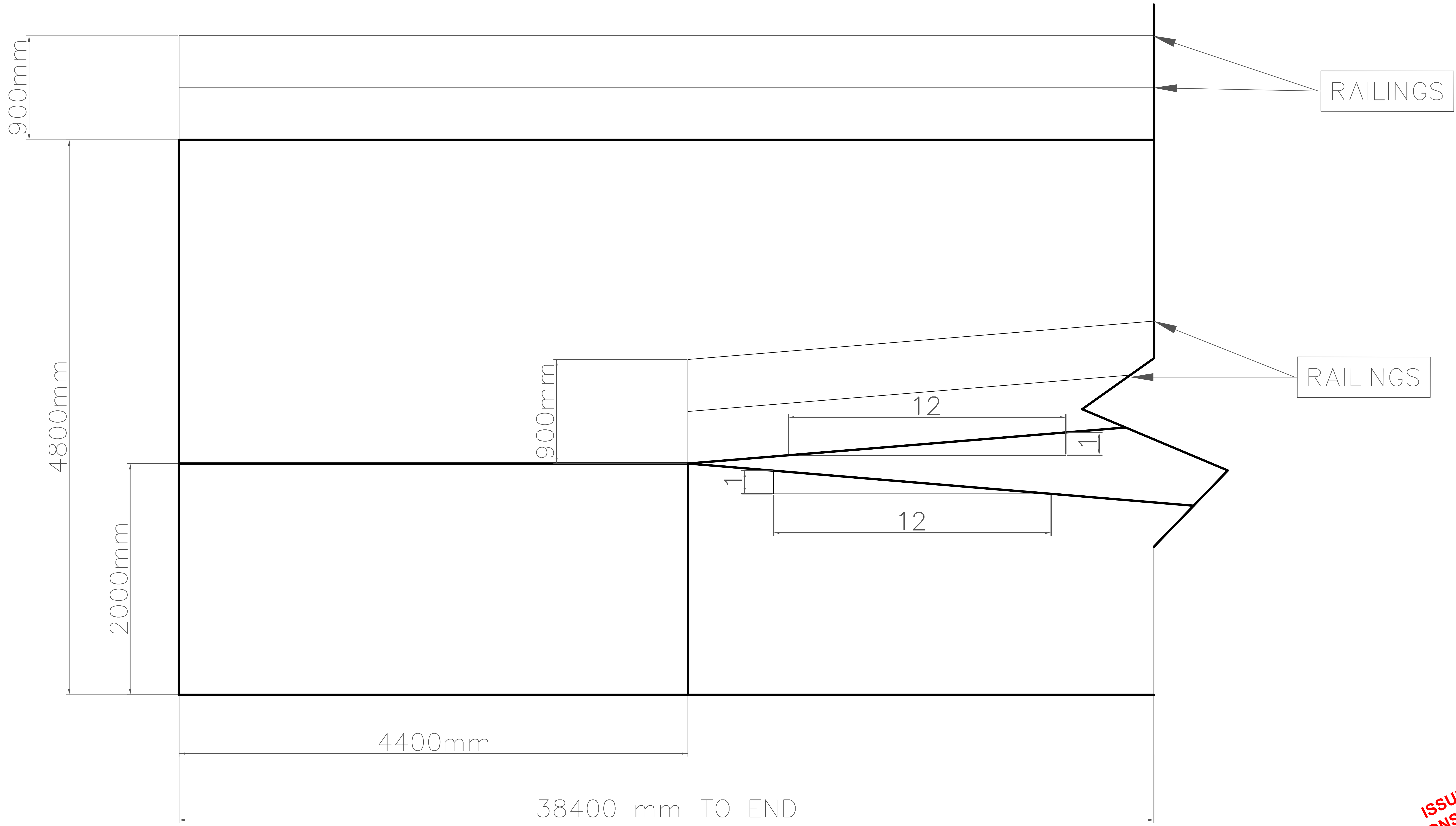

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1	2018-04-09	DETAIL DESIGN	KM

NOTES

1. REINFORCEMENT IN RAMP WALLS WILL FOLLOW SPACINGS AND REBAR SIZES OF DRAWING S-03
2. TYPICAL CONCRETE DEPTHS OF WALKWAYS SHALL BE USED AND CHOSEN BY THE CONTRACTOR ACCORDING TO COMMON PRACTICE
3. REINFORCEMENT WILL FOLLOW POINT 2
4. RAILINGS WILL BE DESIGNED AND CHOSEN ACCORDING TO CONTRACTOR AND MANUFACTURER SPECIFICATIONS AS WELL AS DRAWINGS DIMENSIONS
5. DIMENSIONS MUST FOLLOW DRAWING SPECIFICATIONS TO ADHERE TO NBCC 2010 DIVISION B SECTION 9,8
6. FOR PLAN VIEW, PLEASE REFER TO ROAD DRAWINGS

CONSULTANT

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RAMP SIDE VIEW

SCALE:1:5

DESIGNED JL

DRAWN JL

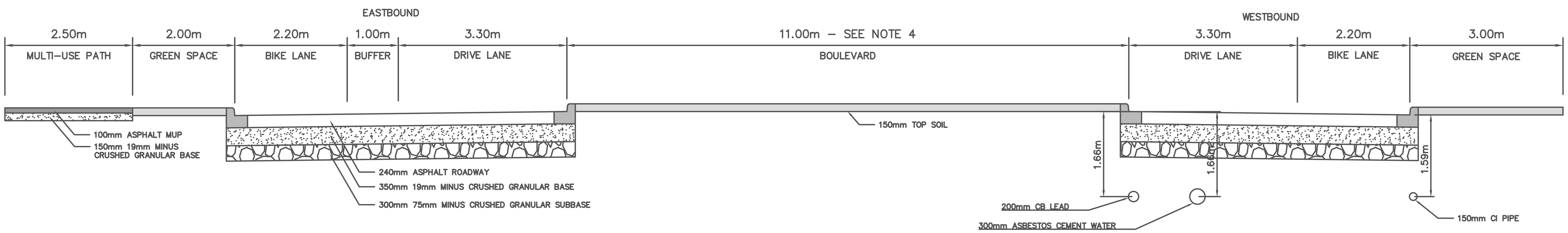
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09

CONSULTANT PROJ. NO. CIVL446

DWG. NO. **R-05**

REV. 1



STATION 0+050
TYPICAL SECTION
SCALE 1:50

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APRIL 9, 2018
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REV.	DATE	DESCRIPTION	BY
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NOTES

1. ERADICATE EXISTING PAINT MARKINGS, ARROWS, STOP BARS AND LANE LINES WITHIN PROJECT LIMITS TO SUIT NEW PAVEMENT MARKINGS AS SHOWN.
2. SAWCUTS TO BE 0.3m FROM GUTTER LIP OR FACE OF CURB AND ON LANE LINE OR CENTRE OF LANE WHERE POSSIBLE TO AVOID WHEEL PATH.
3. ADJUST EXISTING JUNCTION BOXES, MANHOLES, VALVES AND OTHER APPURTENANCES TO MATCH FINISHED GRADE AS REQUIRED.
4. BOULEVARD WIDTH SHALL VARY DEPENDING ON REMAINING WIDTH REQUIRED TO FILL CURB-TO-CURB SPACE.
5. AREA BENEATH DESIGN CROSS SECTION SHALL BE OCCUPIED BY NATIVE FILL.

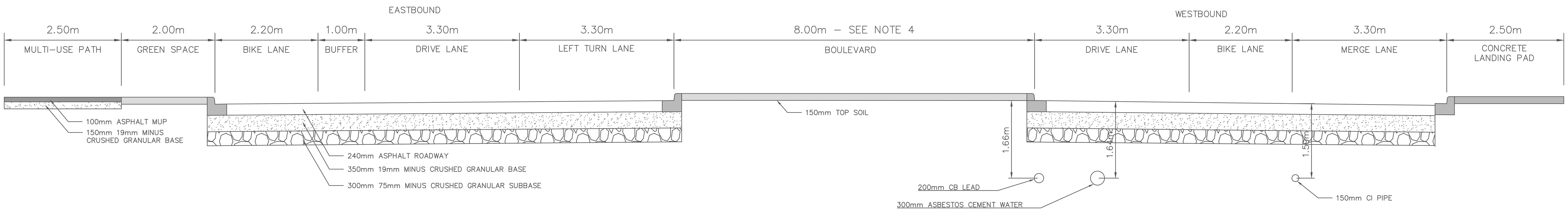
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
PLAN & TYP. SECTION

SCALE: 1:200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-01
REV. 1



STATION 0+230 TYPICAL SECTION SCALE 1:50

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1	2018-04-09	DETAIL DESIGN	KM

NOTES
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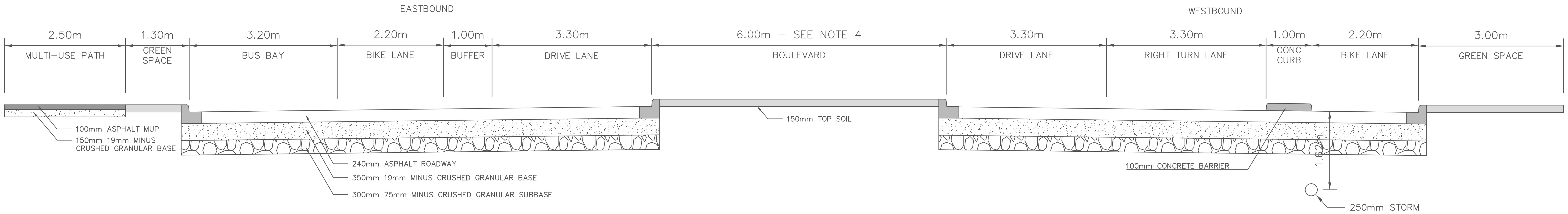
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
PLAN & TYP. SECTION

SCALE: 1: 200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-02
REV. 1



STATION 0+330 TYPICAL SECTION
SCALE 1:50

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1	2018–04–09	DETAIL DESIGN	KM

NOTES
1. ERADICATE EXISTING PAINT MARKINGS, ARROWS, STOP BARS AND LANE LINES WITHIN PROJECT LIMITS TO SUIT NEW PAVEMENT MARKINGS AS SHOWN.
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5. AREA BENEATH DESIGN CROSS SECTION SHALL BE OCCUPIED BY NATIVE FILL.

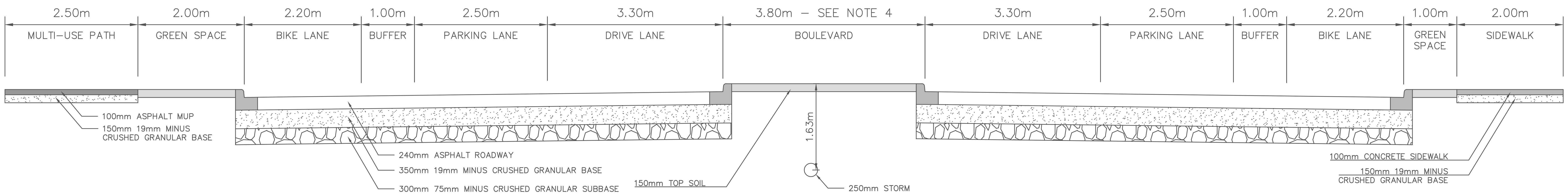
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
PLAN & TYP. SECTION

SCALE:1: 200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **R-03**
REV. 1



STATION 0+510
TYPICAL SECTION
SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
8			
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
1. ERADICATE EXISTING PAINT MARKINGS, ARROWS, STOP BARS AND LANE LINES WITHIN PROJECT LIMITS TO SUIT NEW PAVEMENT MARKINGS AS SHOWN.
2. SAWCUTS TO BE 0.3m FROM GUTTER LIP OR FACE OF CURB AND ON LANE LINE OR CENTRE OF LANE WHERE POSSIBLE TO AVOID WHEEL PATH.
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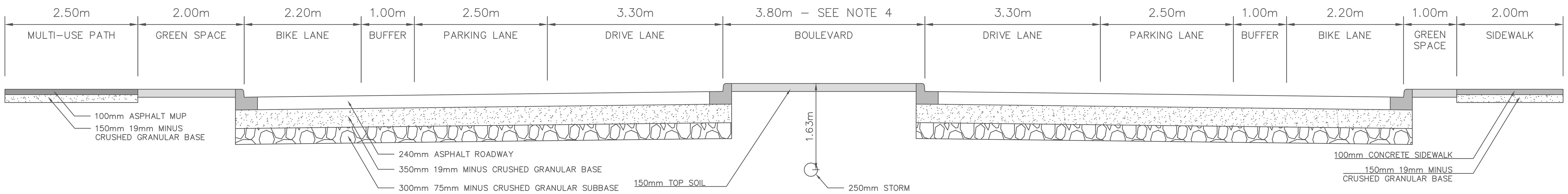
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
PLAN & TYP. SECTION

SCALE: 1:200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-04
REV. 1



STATION 0+680
TYPICAL SECTION
SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
1. ERADICATE EXISTING PAINT MARKINGS, ARROWS, STOP BARS AND LANE LINES WITHIN PROJECT LIMITS TO SUIT NEW PAVEMENT MARKINGS AS SHOWN.
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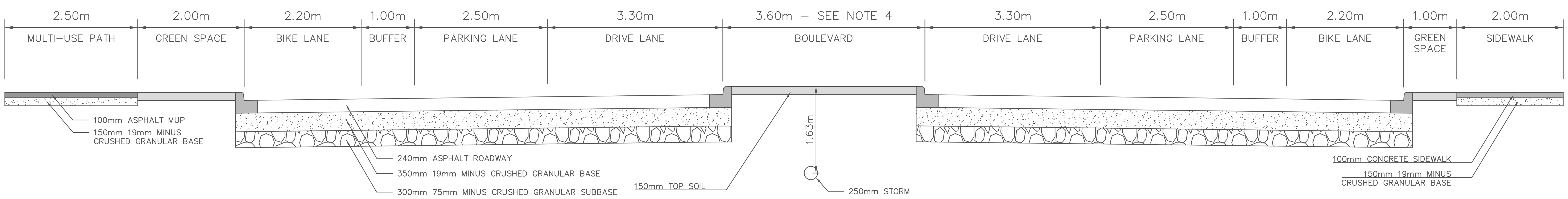
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
PLAN & TYP. SECTION

SCALE:1: 200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **R-05**
REV. 1



STATION 0+820
TYPICAL SECTION
SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
1. ERADICATE EXISTING PAINT MARKINGS, ARROWS, STOP BARS AND LANE LINES WITHIN PROJECT LIMITS TO SUIT NEW PAVEMENT MARKINGS AS SHOWN.
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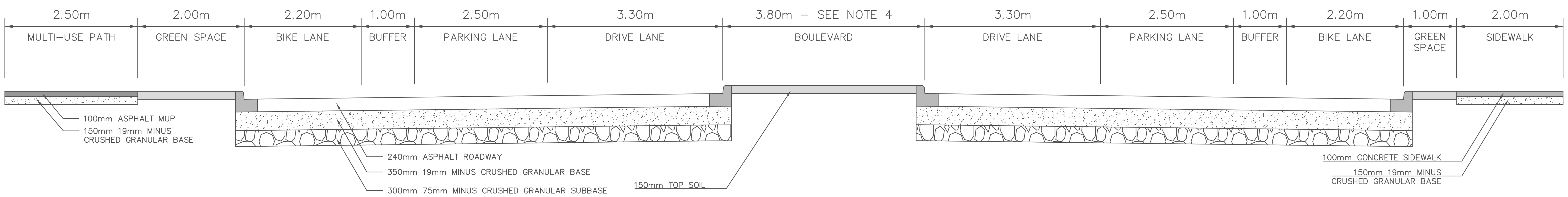
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
PLAN & TYP. SECTION

SCALE:1:200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **R-06**
REV. 1



STATION 0+990
TYPICAL SECTION
SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
8			
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
1. ERADICATE EXISTING PAINT MARKINGS, ARROWS, STOP BARS AND LANE LINES WITHIN PROJECT LIMITS TO SUIT NEW PAVEMENT MARKINGS AS SHOWN.
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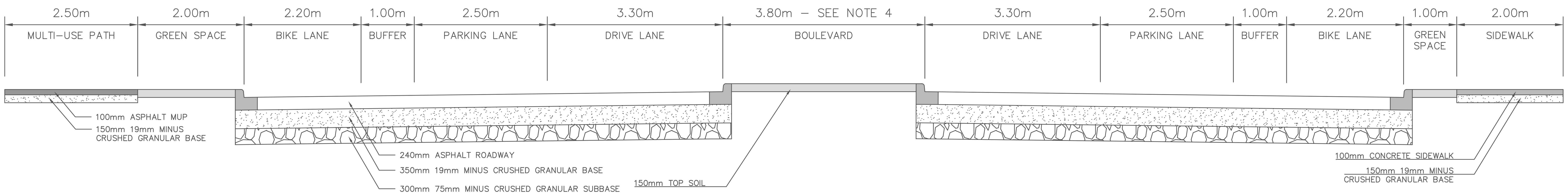
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
PLAN & TYP. SECTION

SCALE: 1: 200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-07
REV. 1



STATION 1+140 TYPICAL SECTION SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	KM

NOTES

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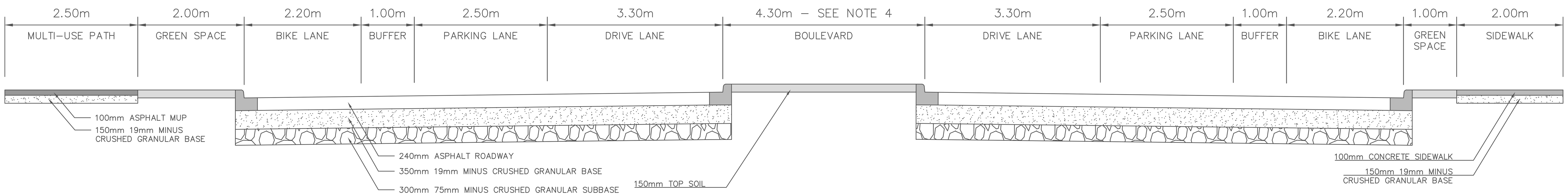
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
PLAN & TYP. SECTION

SCALE: 1:200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **R-08**
REV. 1



STATION 1+280
TYPICAL SECTION
SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
8			
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
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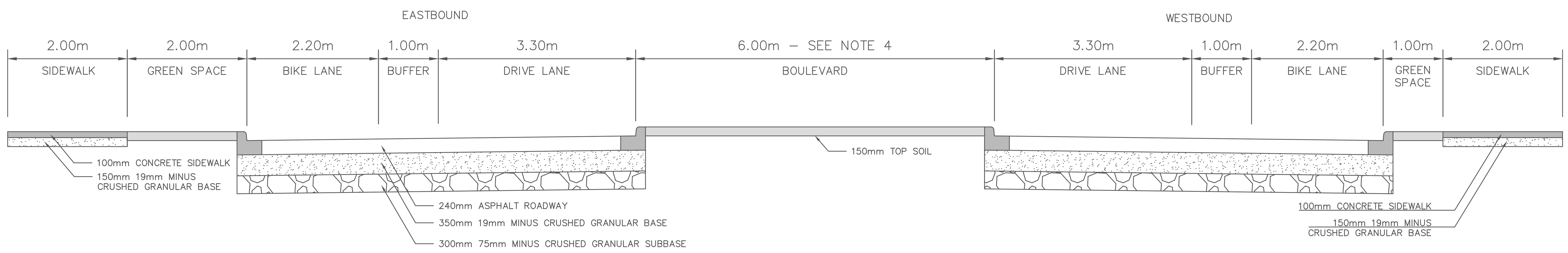
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
PLAN & TYP. SECTION

SCALE: 1:200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-09
REV. 1



STATION 1+430
TYPICAL SECTION
SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
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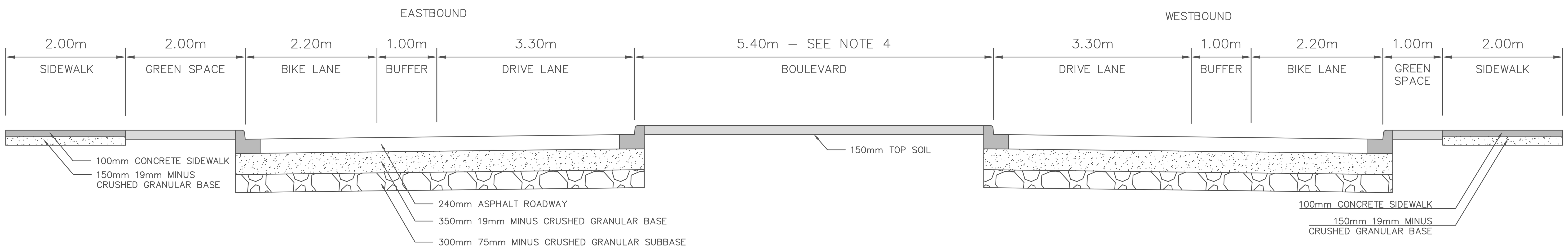
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
PLAN & TYP. SECTION

SCALE: 1: 200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-10
REV. 1



STATION 1+550
TYPICAL SECTION
SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
8			
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
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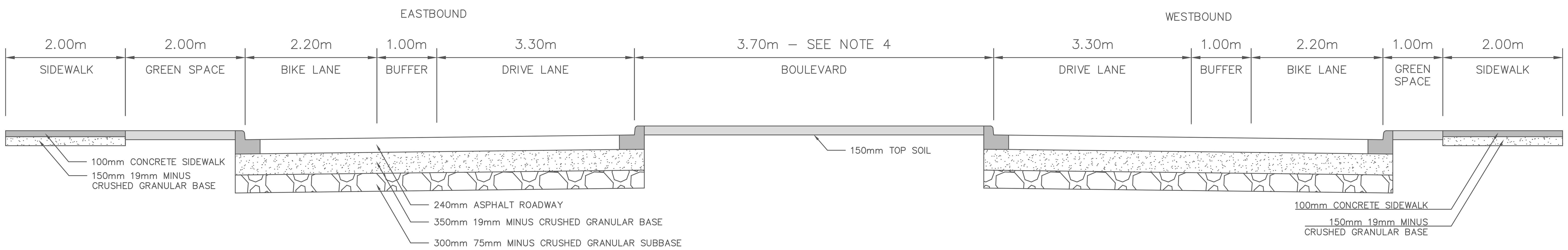
CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
PLAN & TYP. SECTION

SCALE: 1: 200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-11
REV. 1



STATION 1+730 TYPICAL SECTION SCALE 1:50

ISSUED FOR CONSTRUCTION
APRIL 9, 2018
J3MRK Consulting

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	KM

NOTES
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CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
PLAN & TYP. SECTION

SCALE: 1: 200
DESIGNED KM
DRAWN KM
REVIEWED RN

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. R-12
REV. 1

REV.	DATE	DESCRIPTION	BY
8			
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1	2018-04-09	DETAIL DESIGN	RN

NOTES
1. ALL UNDERGROUND UTILITIES TO BE PRE-LOCATED BY THE CONTRACTOR BEFORE CONSTRUCTION WORK BEGINS
2. ALL DRAINAGE FACILITIES TO FOLLOW THE SPECIFIED MMCD & SSD DESIGN DRAWINGS AND SPECIFICATIONS

CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
UTILITIES

SCALE: 1:200
DESIGNED RN
DRAWN RN
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. U-01
REV. 1

REV.	DATE	DESCRIPTION	BY
8			
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1	2018-04-09	DETAIL DESIGN	RN

NOTES
1. ALL UNDERGROUND UTILITIES TO BE PRE-LOCATED BY THE CONTRACTOR BEFORE CONSTRUCTION WORK BEGINS
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CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
UTILITIES

SCALE:1:200
DESIGNED RN
DRAWN RN
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **U-02**
REV. 1

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	RN

NOTES
1. ALL UNDERGROUND UTILITIES TO BE PRE-LOCATED BY THE CONTRACTOR BEFORE CONSTRUCTION WORK BEGINS
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CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
UTILITIES

SCALE:1:200
DESIGNED RN
DRAWN RN
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **U-03**
REV. 1

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	RN

NOTES
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CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE CHANCELLOR BOULEVARD REDESIGN
UTILITIES

SCALE:1: 200
DESIGNED RN
DRAWN RN
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. U-04
REV. 1

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	RN

NOTES
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CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
UTILITIES

SCALE: 1:200
DESIGNED RN
DRAWN RN
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **U-05**
REV. 1

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	RN

NOTES
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CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
UTILITIES

SCALE: 1: 200
DESIGNED RN
DRAWN RN
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **U-06**
REV. 1

REV.	DATE	DESCRIPTION	BY
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1	2018-04-09	DETAIL DESIGN	RN

NOTES
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CONSULTANT
J3MRK Consulting

CLIENT
UBC
CHANCELLOR BOULEVARD

TITLE **CHANCELLOR BOULEVARD REDESIGN**
UTILITIES

SCALE:1: 200
DESIGNED RN
DRAWN RN
REVIEWED KM

DATE (YYYY.MM.DD) 2018.04.09
CONSULTANT PROJ. NO. CIVL446
DWG. NO. **U-07**
REV. 1