UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Corridor Redesign of Chancellor Boulevard - Team 22

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University of British Columbia

CIVL 445

Themes: Transportation, Community, Land

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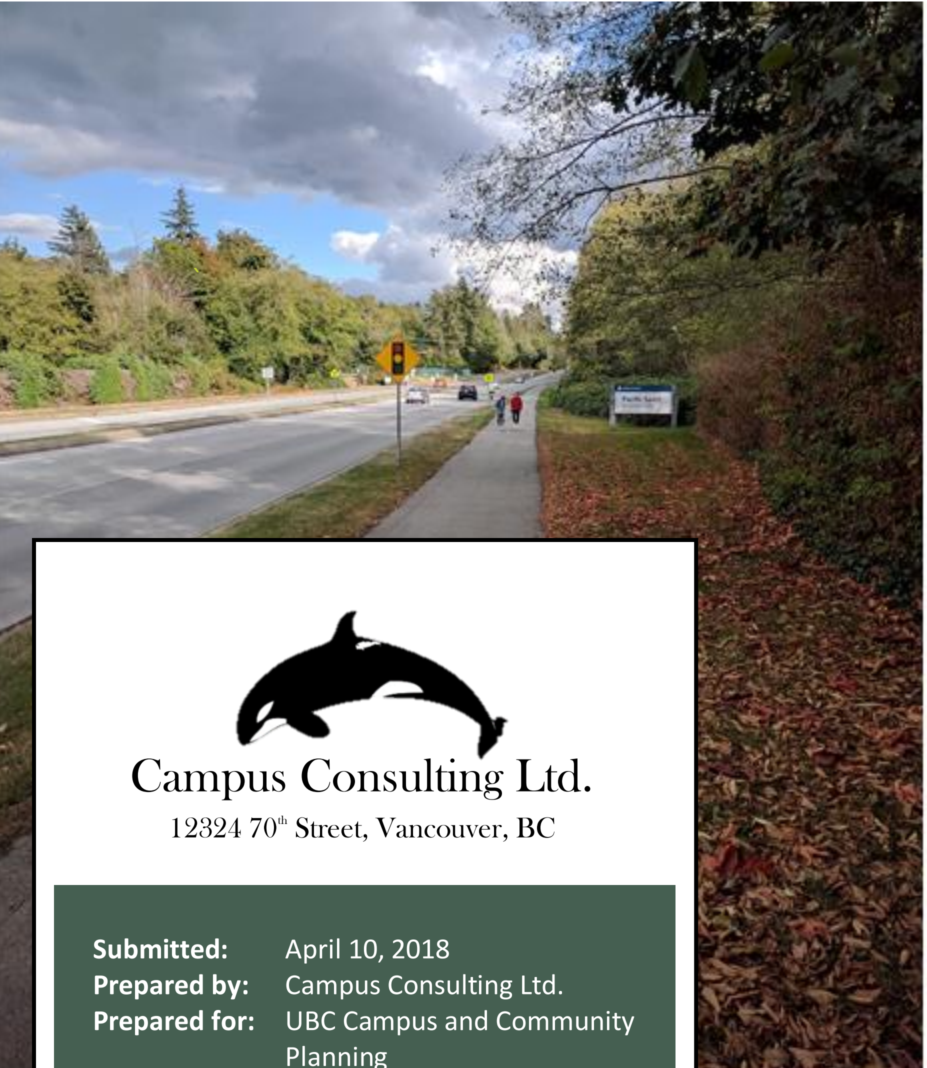

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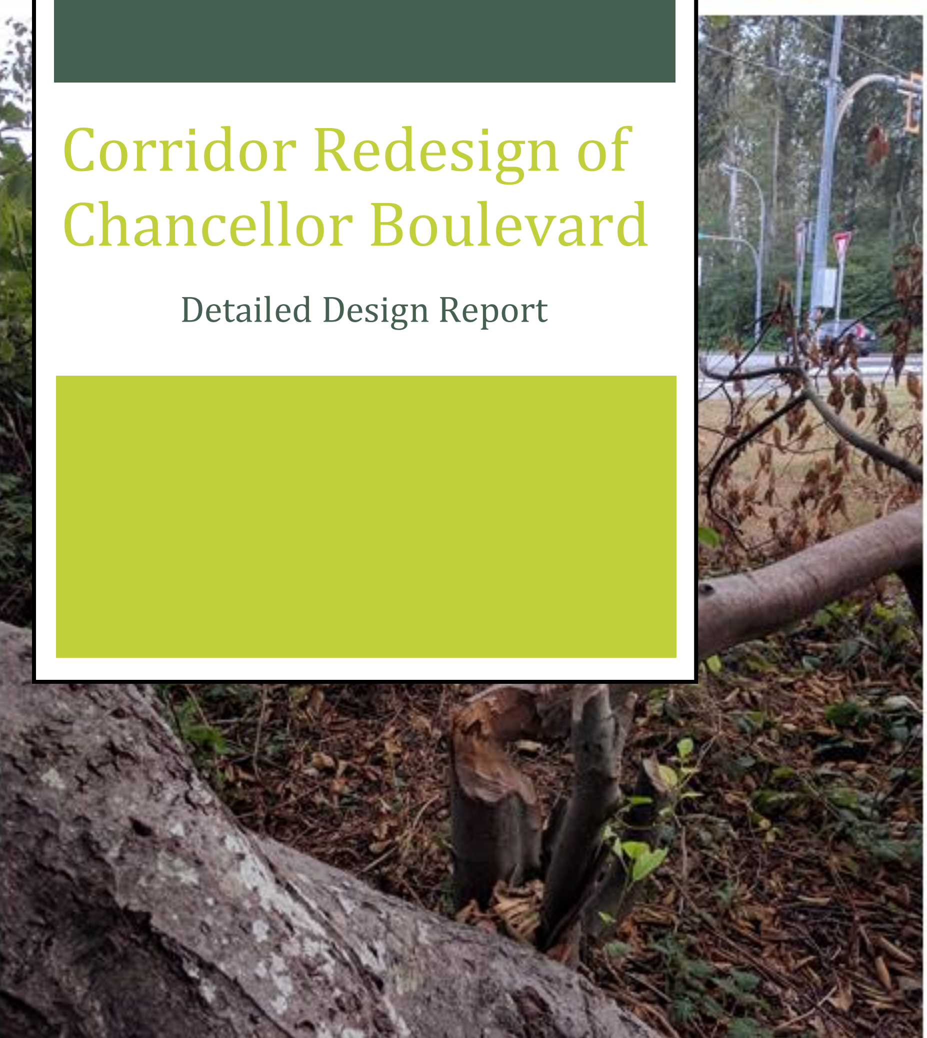
Prepared by: Campus Consulting Ltd.
Prepared for: UBC Campus and Community Planning

Corridor Redesign of Chancellor Boulevard

Detailed Design Report



Executive Summary

Chancellor Boulevard is one of four roads accessing the University of British Columbia's Point Grey campus. The corridor currently experiences heavy vehicle traffic at two peak times per day with drivers routinely exceeding the posted speed of 60 km/hr. In the current design, cyclists must share the road with vehicles as there is no separated or designated bike lane.

Campus Consulting Ltd. was retained to complete both a preliminary and detailed design. The detailed design report herein includes: a grade separated pedestrian underpass, a two-lane road (without a median), a roundabout to slow traffic, and an infiltration swale separating the multi-use path from the road to infiltrate road runoff.

The Corridor Redesign of Chancellor Boulevard provides an opportunity to address some of these key issues as well as other identified issues including stormwater management, environmental protection, geotechnical concerns, and stakeholder concerns. The objectives governing the redesign process include:

- meeting all future transportation demands,
- prioritizing buses, cyclists, and pedestrians and ensuring the safety of all road users,
- avoiding negatively impacting Pacific Spirit Park and the habitats it provides,
- accommodating and improving drainage, and
- minimizing costs and optimizing the construction schedule.

The updated cost of the design is $3.86 million, an increase from $3.43 million as estimated during the preliminary design phase.

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1. Project Understanding

Campus Consulting Ltd. has been retained by UBC Campus Community Planning to provide detailed design engineering services and service-life maintenance planning for the Chancellor Boulevard Redesign Project on the UBC Vancouver campus. This Detailed Design Report for the Chancellor Boulevard Redesign Project follows the previously issued Preliminary Design Report (November 28, 2017).

Chancellor Boulevard, which is an arterial road extending from West 4th Avenue and one of four gateways onto the UBC campus (*Figure 1-1*), is in need of a redesign to increase mode share along the 1.8 km corridor to give priority to pedestrians, cyclists, and buses while at the same time reducing traffic speed to 50km/h to increase safety for road users. The corridor is in need of a grade separated pedestrian crossing to provide a safe crossing for pedestrians and cyclists accessing University Hill Elementary School and the trails connecting Pacific Spirit Park.

Figure 1-1: Location of project

1.1. Design Objectives

UBC Campus Community Planning has prioritized the following design objectives:

- meet all future transportation demands
- prioritize buses, cyclists, and pedestrians and ensure the safety of all road users
- avoid impacting Pacific Spirit Park and the habitats it provides
- accommodate and improve drainage
- minimize costs and optimize the construction schedule

Each of these objectives were integral during the design process and have been met through various design features.

1.2. Key Issues

1.2.1. Design Speed and Driver Speed

The posted speed limit in the corridor is 60km/hr (*Figure 1-2)*, but typical traffic speeds exceed this speed limit. A reason for this is the road design - the road is currently a four-lane divided highway with gentle horizontal and vertical curves and long sight distances, which encourages speed along this section of the corridor, especially after the relatively tight sections of road that precede and follow.

Figure 1-2: Typical section of roadway along Chancellor Boulevard

Figure 1-3: A jaywalking desire path has formed to connect two trailheads on opposite sides of Chancellor Boulevard

1.2.2. Pedestrian Safety

University Hill Elementary School and Pacific Spirit Park are located along the corridor, so there are many pedestrians using the corridor. Both driver speed and lack of pedestrian crossings presents a pedestrian safety issue. Currently, the corridor only has one pedestrian-controlled crossing at the elementary school but no other protected crossings. Several trails in Pacific Spirit Park are bisected by the corridor including Salish Trail, and Pioneer Trail. Despite driver speeds and a lack of protected crossings, there is evidence of pedestrian and bicycle crossings near the Pacific Spirit Park trailheads that exit along the corridor, as seen in *Figure 1-3*. There is one existing multi-use path along the south side of the corridor but it is in disrepair in some areas, making the pathway less navigable for some users, and discourages cyclists from using it.

1.2.3. Bicycle Safety

This stretch of Chancellor Boulevard does not currently provide bike lanes even though West 4th east of Drummond road and Chancellor boulevard west of Acadia Road both include at grade bike lanes (*Figure 1-4)*. The lack of bike lanes means cyclists are forced to share the road with cars travelling above the speed limit, or ride on the poorly maintained multi-use path, which can interfere with pedestrians, drivers, and transit.

Figure 1-4: Bicyclist choose to ride on Chancellor Boulevard despite the lack of bike lanes

Figure 1-5: Evidence of beaver habitation in the stream adjacent to University Hill Elementary

1.2.4. Preservation and Improvement of Local Environment

Chancellor Boulevard bisects the northern part of Pacific Spirit Park, a 763 hectare nature preserve with a large variety of ecosystems including wetlands, meadows, and dense coastal forest (*Figure 1-5)*. Development throughout the park is minimal to keep it as natural as possible. Any development nearby has the potential to impact these precious ecosystems, which is why the effects due to the project will be considered and carefully mitigated.

1.2.5. Drainage Improvements

Existing drainage management involves both built and natural drainage networks including roadside ditches, stormwater sewers, culverts, and three natural catchments that drain towards the ocean. The existing drainage is performing adequately, but improvements to stormwater quality and volume reduction could be made in keeping with UBC's Integrated Stormwater Management Plan.

1.1.1. Stakeholder Concerns

Chancellor Boulevard connects many of UBC's surrounding neighbourhood's and community services and as such, the project requires input from many stakeholder groups. Stakeholder consultation is critical to the success of the project to ensure the redesign encompasses their vision for the corridor. Much of the feedback collected to date was incorporated in the detailed design and will continue to be considered throughout the next phases of the project (as seen in *Figure 1-6*).

Figure 1-6: UBC Endowment Lands neighborhood on west end of project

1.3. Task Register

	Task	Person Responsible
SEED Cover		Megan Norwick
Letter of Transmittal		Megan Norwick
Executive Summary		Stuart Martinson
Table of contents		Megan Norwick
Project Understanding		Megan Norwick
	Introduction	Megan Norwick
	Design Objectives	Megan Norwick
	Key Issues	Megan Norwick
	Design Criteria	Megan Norwick
Existing Conditions		
	Traffic Analysis	Chris Pertch
	Environmental Assessment	Megan Norwick
	Stormwater Assessment	Stuart/Megan
	Stakeholder Engagement	Katrina Ong
	Geotechnical Analysis	Stuart Martinson
	Pavement Condition	Brad Krahn
	General Soil Conditions	Stuart Martinson
Detailed Design		
	Pedestrian Underpass	Stuart Martinson
	Roadway	Bain Konway
	Stormwater Management	Stuart/Megan
	Construction Specifications	Chris Pertch
	Construction Sequence	Chris Pertch

	Anticipated Issues	Chris Pertch
	Construction Cost	Chris Pertch
	Operations and Maintenance	Chris Pertch
Conclusion		Megan Norwick
Software & References		All
Appendix A: Species List		Megan Norwick
Appendix B: Underpass Sample Calculations		Brad Krahn
Appendix C: 2016 MOTI Standards for Highway Construction Specifications		Chris Pertch
Appendix D: Detailed Construction Schedule		Chris Pertch
Appendix E: Updated Cost Estimate		Chris Pertch
Drawing Package		Bain and Katrina

2. Existing Conditions

2.1. Traffic Analysis

A detailed traffic analysis was conducted to identify traffic issues the corridor was experiencing and the current level of service for the intersection. The analysis included a traffic count, site observations, and computer modelling, which identified areas of improvement and provides suggested techniques for mitigating identified issues.

2.1.1. Existing Conditions

It was observed that the corridor operates efficiently and is appropriately sized during peak hour traffic, but it is grossly overdesigned for off-peak hours. This type of overdesign can give rise to issues such as speeding and driver complacency. Site visits were undertaken to provide general observations as well as to conduct a traffic count during peak hours. Several observations of traffic concerns include:

- Excessive speeding
- Illegal U-Turns at the intersection of Hamber Road and Chancellor Boulevard
- Unsafe vehicle maneuvers around cyclists using the roadway
- Pedestrian jay walking

The traffic count, which was completed on September 28th, 2017, is summarized in *Table 2-1.*

Table 2-1: Unsafe Traffic Occurrences During Peak Hour Flow

Unsafe Traffic Occurrences During Peak Hour Flow				
	Excessive Speed	**Illegal U-Turns**	**Unsafe Turns**	**Jay-Walking**
Instances per Hour [1]	12	6	11	2

[1] Only includes instances observed in direct vicinity of Hamber & Chancellor intersection. Actual number of instances along entire length of corridor may be higher. Instances of unsafe behaviour were assessed visually.

During the count, it was revealed that a regular amount of heavy vehicles (buses, trucks, etc.) were observed and as such our analysis accounts for 5% heavy vehicles by traffic volume. Typical analysis uses a 1-2% annual traffic growth rate, however, because both UBC and the City of Vancouver are undertaking policies to reduce personal vehicle use, current traffic levels are more likely to decrease in coming years [1] [2]. Therefore, modelling uses present day values for all design analysis. The peak hour volume results used for traffic analysis are summarized in *Table 2-2* below.

Table 2-2: Peak Hour Traffic Volumes at Intersection of Chancellor Blvd & Hamber Rd

Present Day Peak Hour Summary (All Vehicles)							
	Chancellor Blvd Eastbound		**Chancellor Blvd Westbound**		**Hamber Rd Southbound**		
	Through	**Right**	**Through**	**Left**	**Left**	**Right**	**Total Peak Hour Traffic**
AM Peak Hour	756	70	210	103	46	91	1276

2.1.2. Results

Synchro 6 was used to model the existing intersection under existing conditions. The Level of Service (LOS) and average delay for each approach was analyzed, as well as an overall rating determined for the intersection. These conditions are summarized in *Table 2-3* below.

Table 2-3: Summary of Existing Intersection Performance at Present Day

Existing Intersection Condtions			
	Chancellor Blvd Westbound	**Chancellor Blvd Eastbound**	**Hamber Rd Southbound**
	Thru/RT	**Thru/LT**	**LT/RT**
LOS	A	A	F
Delay (Sec)	0	5.8 (Thru), 3.1 (LT)	143.6
Overall Intersection LOS		D	
Overall Intersection Delay (Sec)		20.0	

The intersection currently operates under an acceptable LOS, except for left turning traffic leaving the elementary school from Hamber Road which has a very poor level of service. This result agrees with observations made during the traffic count. Under peak traffic, left-turns from Hamber are often forced to wait until pedestrians trigger the crosswalk on Chancellor. Due to the long wait, drivers often choose to turn right onto Chancellor boulevard and perform illegal U-turns at Acadia Road to the west in order to shorten their wait.

2.1.3. Design Solutions

The following solutions, guided by NACTO's Urban Street Design Guide [3], have been designed to alleviate the above noted concerns and include:

- narrowing the roadway
- removing the boulevard to create a 2-way street
- including bike lanes along the corridor
- visually narrowing the roadway through tree planting and other foliage
- adding pedestrian crosswalks at the three major trail heads into Pacific Spirit Park

To address the poor level of service for left-turning traffic from Hamber Road, a roundabout has been designed to better accommodate school traffic during the peak morning hours and double as a traffic calming feature.

2.2. Environmental Assessment

An Environmental Assessment (EA) was conducted to identify environmentally sensitive areas and take inventory of all Species At Risk within the project area. The findings of the EA, the identified regulatory requirements, and implemented mitigation measures are below.

2.2.1. Background

Chancellor Boulevard bisects Pacific Spirit Park, a 874 hectare nature reserve owned by the government of British Columbia, within the University Endowment Lands. The park consists of several ecologically important ecosystems including mature forest, young forest, wetlands and riparian habitat. Salish (Acadia) Creek and Spanish Banks Creek provide spawning and rearing habitat for Chum and Coho salmon, after restoration efforts were recently made to return them to salmon-bearing status, and therefore are of particular importance due to their proximity to the project.

2.2.2. Assessment Methods

A desktop study and literature review was conducted using the following resources:

- Government of Canada Habitat Stewardship Program brochure
- BC Species and Ecosystems Explorer

- BC Conservation Data Centre database (CDC)
- Metro Vancouver Sensitive Ecosystem Inventory

Using the CDC database, results for flora and fauna were compiled and sorted based on their red, blue, or yellow BC listing (Appendix #).The rankings, described below, highlight the risk-status of wildlife and plant species as well as natural plant communities in BC:

- Red – Extirpated (X), Endangered (E), or Threatened (T) in BC
- Blue – not immediately threatened but of Special Concern in BC
- Yellow – Not at Risk in BC

These designations are used in this report to indicate the status of species and ecosystems observed with respect to the provincial listings of species at risk. A site survey was conducted on October 19, 2017 to field truth sensitive areas found during the desktop study, with a specific focus on riparian areas and streams. Regulatory considerations for the project were identified as follows:

- Federal
  - Species at Risk Act (SARA)
  - Fisheries Act
- Provincial
  - BC Wildlife Act
  - Riparian Areas Regulation (RAR)
- University Endowment Lands (UEL)
  - Official Community Plan
  - Land Use, Building and Community Administration Bylaw
  - Works and Services Bylaw
  - University Endowment Land Act

2.2.3. Results

The Sensitive Ecosystem Inventory revealed that the project area is within an area generally considered as sensitive with the following sensitive ecosystems being identified: mature forest, young forest, wetlands and riparian habitat. Identification of environmentally sensitive areas allows for the creation of action plans to be implemented that help maintain and improve those ecosystems that provide valuable ecosystem services. The protection of Salish (Acadia) Creek and Spanish Banks Creek, which were identified as being salmon-bearing, supports Metro Vancouver's long-term action plan for supporting salmon in the cities.

Results from the CDC database search results are provided in *Appendix H*. A summary of the number of flora and fauna species returned in the database search is presented below in *Table 2-4*.

Table 2-4: Listed species within project area

	Amphibian / Reptile	Bird	Invertebrate	Mammal	Plant	Fish
Red	3	2	5	1	1	3
Blue	1	4	-	-	2	-
Yellow	1	-	-	1	-	-

No active raptor or migratory bird nests were observed during the site reconnaissance survey, nor were any inactive nests observed. A beaver dam was noted near the southern end of Salish Creek, though it appeared it had previously been altered to allow for drainage with a small, metal culvert.

2.2.4. Recommendations

Environmental recommendations fall into two categories: protection of salmon-bearing streams and protection of species at risk. The proximity of salmon-bearing streams will require additional mitigation measures during construction to protect the streams from sediment runoff but the project also provides an opportunity to improve existing stream conditions by improving water quality. An Environmental Management Plan (EMP) will be prepared prior to construction, which will include an Erosion and Sediment Control (ESC) Plan outlining key mitigations to implement during construction to protect nearby drainages. In addition, green stormwater infrastructure could help improve water quality by filtering all road runoff prior to it entering the streams.

Several red- and blue- listed flora and fauna were identified. Of those species identified, those considered to be likely occurring within the project area, based on habitat preference, were investigated further and mitigations for potential effects were focused on these species. Although construction activities will not directly interact with riparian habitat, relocation of some amphibian, invertebrate and small mammal species may be required in areas peripheral to the nearby streams if construction activities have the potential to cause disturbance. The necessary wildlife handling and salvage permits would be obtained and any relocations would be completed by a Qualified Environmental Professional.

2.3. Geotechnical Analysis

A geotechnical study was conducted which showed that Point Grey is comprised of fluvial sedimentary deposits formed in a large delta between 50,000 and 20,000 years ago by a forebear of the Fraser River. The area was previously glaciated and the land that is now the peninsula was below sea level. After glacial retreat, the soil rebounded to its current elevation, approximately 60 metres above sea level.

2.3.1. General Soil Conditions

Stratigraphy remains consistent across Point Grey peninsula for the most part, though the thicknesses of the strata vary. These strata are tabulated below in *Table 2-5*.

Table 2-5: Point Grey peninsula stratigraphy

Elevation (m ASL)	Stratum	Description
68 - 69	Capilano Sediments	Beach Gravels and/or glaciomarine silt to clay loam
65 – 68	Vashon Drift	Sandy, loamy lodgement till
20 - 65	Quadra Sand Unit Q1	Fine to coarse sand, with minor silt and gravel
12 – 20	Quadra Sand Unit Q2	Interbedded silt, fine sand, and minor peat
10 – 12	Quadra Sand Unit Q1	Fine to coarse sand, with minor silt and gravel
3 - 10	Quadra Sand Unit Q2	Interbedded silt, fine sand, and minor peat
0 - 3	Quadra Sand Unit Q1	Fine to coarse sand, with minor silt and gravel

The Vashon Drift stratum underlying the site is less permeable than the layers above and below it, and it undulates and varies in thickness. Water that infiltrates the surface layer perches on top of it and ultimately runs laterally to the cliffs on the edge of the peninsula where causes mass wasting and erosion. In locations where groundwater cannot reach the cliffs, it accumulates and slowly percolates into the Vashon Drift. Evidence of this is seen on the surface in the form of bogs. The Quadra Sand Unit Q1 is significantly more permeable than both the overlying till and the underlying Quadra Sand Unit Q2.

This layer is hence called the Upper Aquifer. The Quadra Sand Unit Q2 is an aquitard that transmits accumulating groundwater laterally where it seeps out of the cliffs. Groundwater that seeps through the aquitard enters the Lower Aquifer, where it again accumulates over the lower layer of Quadra Sand Unit Q1. Water that runs laterally seeps out of the base of the Point Grey Cliffs. As development on the peninsula has increased, so too has the ratio of impervious to pervious ground. This has forced infiltration to increase in the remaining pervious areas, ultimately leading to increased seepage at certain locations on the cliffs which has decreased slope stability and increased erosion.

2.3.2. Pavement Condition

Cracking along the corridor was observed but no settlement or rutting of the roadway was observed, indicating that the road base is in good condition. The current pavement surface conditions are drivable but will worsen over time due to heavy vehicle weight. It is recommended to use a combination of mill and overlay, as well as repaving select areas to improve roadway safety and road user comfort.

The main road section between Hamber Road and Drummond drive could be milled and overlain, while the intersections of Hamber Road and Drummond Drive require complete removal and pavement replacement due to extensive cracking of pavement. This will ensure the best quality of road surface along Chancellor Boulevard for safety and comfort of road users. *Table 2-6* summarizes the existing road conditions.

Table 2-6: Pavement condition summary

Location	Condition	Recommended Construction Method
Hamber Rd. Intersection	• Longitudinal Wheel Path Cracking (LWP): moderate • Alligator Cracking (AC): moderate • General: poor condition, minor potholes beginning	Full-depth reconstruction
Westbound	• Longitudinal Wheel Path Cracking (LWP): low to moderate • Alligator Cracking (AC): moderate • General: fair condition, no rutting or potholes	Mill and overlay
Eastbound	• Longitudinal Wheel Path Cracking (LWP): low to moderate • Alligator Cracking (AC): moderate • General: fair condition, no rutting or potholes, Right lane resurfaced	Mill and overlay
Drummond Dr. Intersection	• Longitudinal Wheel Path Cracking (LWP): moderate • Alligator Cracking (AC): moderate • General: poor condition, minor potholes beginning	Full-depth reconstruction

2.3.3. Recommendations

The hydrogeology of the University of British Columbia's Point Grey campus has been well researched, and from this several recommendations have been made to guide safe development on campus. Some of these recommendations are applicable to the redesign of Chancellor Boulevard, especially the design of the tunnel and utility trenches. Past reports recommend that:

- Building and foundation trenches should be sealed, and perimeter drainage should be piped to storm drains
- Service trenches should have diversion barriers with diversion drains, to prevent the trenches from acting as conduits for groundwater

The recommendations above should be followed closely, and a monitoring regime should be implemented to ensure that no ill effects arise as a result of increased infiltration along the road corridor. Dewatering wells have been drilled near the cliffs on UBC's campus with some success and, if necessary, more may be drilled to mitigate new problems.

In addition to the above recommendations, it is essential that a thorough geotechnical investigation and site characterization specific to this site take place. At least one borehole investigation should take place at the location of the proposed tunnel, and boreholes and surveying will be necessary along the length of the corridor to determine the localized soil profile in order to minimize the amount of full depth reconstruction required.

2.4. Stormwater Assessment

2.4.1. Existing Conditions

The corridor runs through three catchments. In the current design, all but a very small portion of road runoff is discharged untreated into four outfalls in the Spanish, Canyon, and Salish (also known as Acadia) Creeks in Pacific Spirit Park. The remainder flows overland into a ditch on the Northside of Chancellor Blvd. where it is conveyed to Spanish Creek. In a recent investigation, sampling of the levels of aluminum, copper, manganese, and zinc, metals present were measured in the creeks and have been shown to exceed guidelines. The salmon populations in these creeks were thought to have been wiped out, but salmon have been observed recently in both Spanish and Salish Creeks in addition to the populations of resident trout (*Figure 2-1*).

Figure 2-1: Culvert outlet in riparian zone adjacent to Chancellor Blvd.

2.4.2. Climate Change Considerations

Intensity-Duration Frequency (IDF) curves are the result of analysis of extreme precipitation events over a period long enough to be statistically significant and form the basis for the design of stormwater management infrastructure such as culverts and drain pipes. These IDF curves are based on historic data, but as the climate changes, so do the patterns of local rainfall. Because of this, efforts are being made to update current IDF curves. This is important because if municipal infrastructure is designed using underestimated rainfall, it will not be able to handle increased future stormwater loads. Conversely, it is also important to be able to predict future droughts. A study initiated by Metro Vancouver and performed by BGC Engineering has developed IDF curves based on data from ten measurement sites. The curves are adjusted to the year 2050, and based on an extreme climate change scenario based on increased emission levels from now until then.

2.4.3. Recommendations:

Based on the conservative climate scenario, monthly precipitation in Metro Vancouver will increase by 10-21% by the year 2050. Also, the frequency of extreme events will increase significantly, especially at lower durations. At most of the stations, what is now a 100-year storm will be a 50-year storm in 2050. As a result, any design features should be able to convey these higher peak flows while also being able to more effectively filter the metals and other roadside pollutants.

2.5. Stakeholder Engagement

Several stakeholders will be affected by the project during all phases; planning, construction, operation and decommissioning. The goal is to design the project such that stakeholder concerns are addressed. Data throughout the preliminary design stage was collected and incorporated into the detailed design and continued communication with the relevant parties has taken place throughout the progression of the design.

The stakeholder engagement strategy began with a stakeholder analysis. This process involved compiling a list of stakeholders, obtaining information on other unforeseen stakeholders, and researching the interested parties to determine their core values. In addition to the independent study done to understand the needs of project stakeholders, continuous communication with stakeholders was made a priority. To date, stakeholder data has been collected through surveys to the general public, formal meetings with stakeholder officials/representatives, and through an open-house forum.

Inputs from stakeholders has been compiled and analyzed to inform the direction of the project. This input was be measured against current standards and regulations in order to provide project options. Since the majority of those providing feedback and suggestions are lay-people, stakeholder input was considered in relation to proven solutions within the scope of engineering. Not all initiatives will purely be design based. For example, changes in transportation and street-use behaviours, education on new signage and use of the new intersections is equally important to the effectiveness of the solutions provided.

Several lines of communication will remain open during and after project construction. The performance of the corridor and subsequent satisfaction of stakeholders will not be known until the Chancellor Boulevard is fully reopened and is being used during peak demand times. The recommendation is for BC Ministry of Transportation and Infrastructure (MOTI) to provide a feedback focused email account. This should remain under the responsibility of TranBC, the online face on MOTI. Major milestones of the project will continue to be communicated through a project website to ensure the public can readily access the information that pertaining to this redesign.

3. Detailed Design

3.1. Pedestrian Underpass

It was determined that an underpass would be the best suitable option for providing a safe passage across the Chancellor Boulevard corridor for pedestrians and cyclists crossing near the University Hill Elementary School. The tunnel will be constructed from cast-in-place reinforced concrete will have a width of 4.5 m and a clear height of 2.5m and consist of six elements: a suspended slab, two bearing/retaining walls, each supported by a strip footing, and a slab on grade. Design loads for the concrete elements were taken from CSA-S6-06, and their calculations can be found in Tables 2 and 3 of Appendix A. All concrete elements were designed to the CSA A23.3-14 standard. An MSE wall will stabilize the slope on the approach to the underpass.

The design of the retaining walls will have the capacity to sustain both flexural and axial loads. Flexural loads imposed on the wall include at-rest lateral earth pressures as well as worst-case lateral pressures based on traffic surcharges. Bearing capacity and axial loads were based on the assumption that tire area would be imposed directly onto the top of the wall. Strip footings were designed based on the soil bearing capacity, friction angle, and geotechnical reduction factor in the supplied geotechnical report. The slab on grade was designed for pedestrian loads therefore a 150mm thickness with temperature reinforcement was found to be sufficient. Required dimensions were calculated for the MSE wall section and an appropriate Nilex MSE wall system was chosen to suit. Design loads were the same as those used for the concrete tunnel elements. Tire loads are assumed to be imposed at a 3m distance from the edge of the wall.

3.2. Roadway

3.2.1. Design Speed and Alignment

With the goal of reducing traffic speeds along the corridor, the design seeks to reclassify the road as an undivided arterial urban road, 2-lane UAU50, by the removal of the south 2 lanes. Horizontal circular curves that do not utilize super-elevation or reverse crown will be implemented in keeping with typical municipal urban design guidelines. The design will retain the existing alignment and cross-sections but will modify the intersection. Table 3-1 indicates the minimum design values.

Table 3-3-1: Minimum Design Values

Design Feature	Parameter	Minimum Value
Horizontal Circular Curve	Radius (no superelevation)	100m
Horizontal Circular Curve with Spiral	Radius (4% superelevation)	80m
Spiral Length	Ls	22m
Crest Curve	K Value (Stopping Sight Distance)	7
Sag Curve (no illumination)	K Value (Stopping Sight Distance)	13
Sag Curve (illuminated road)	K Value (Comfort Control)	6
Laning	Width	

3.2.2. Intersection Design

Campus Consulting conducted an intersection analysis to determine the best suited option given the design objectives of the project. Modelling for stop sign and signalized options was completed using Synchro 6 while Sidra Intersection 7.0 was used to better reflect roundabout conditions. Level of service, user safety, intersection delay, and cost were compared in a multi-point evaluation, with a roundabout being the preferred option. The roundabout was designed as per NCHRP 672 Roundabouts: An Informational Guide and BC Supplement to TAC Geometric Guidelines. The roundabout geometry is summarized in Table 3.2 and the detailed design can be found in the attached design drawings.

Table 3-2 Roundabout Geometry

Design Feature	Value
Inscribed Circle Diameter	40m
Raised Central Island Diameter	16m
Circulatory Roadway Width	6m
Entry Radius	20-30m
Exit Radius	120m
Fastest Path	35km/hr

3.2.3. Pedestrian and Bike Improvements

Given the importance of increasing pedestrian and cyclist safety along the corridor, buffered bike lanes on the roadway, with a 1.5m wide bike lane and 0.6m buffer will be provided, designed to the NACTO Urban Bikeway Design Guide. For cyclists that do not feel comfortable on the roadway, the existing multi-use path will be widened to 3.0m and resurfaced to allow pedestrians and bicyclists to use the path together. In addition, overhead pedestrian crossing lights will be added at major trailheads with Pacific Spirit Park so that pedestrians have safe crossing locations.

3.2.4. Paint markings and signage

Additional road signs and markings will be implemented and will conform to BC Ministry of Transportation and Highways Manual of Standard Traffic Signs & Pavement Markings and City of Vancouver regulations on street signs and signals. Additionally, roundabout signage is designed to meet industry standard practice by satisfying signage requirements of the Transportation Association of Canada Manual of Uniform Control Devices for Canada.

3.3. Stormwater Management

Campus Consulting performed a hydraulic analysis of the Chancellor Boulevard using PCSWMM to determine a new stormwater management plan for the project area. A new stormwater system was designed to manage 100-year floods, taking into account projected increases in precipitation due to climate change. This system is comprised of two distinct source control sub-systems: a bioswale to collect runoff from the road, and a set of lawn basins to collect runoff from the area around the pedestrian underpass.

Roads will be sloped such that runoff from the road will flow into a bioswale designed to infiltrate 90% of annual precipitation and 90% of a 2-year 24-hour storm event. The design includes a 150 mm perforated underdrain and a trapezoidal drain rock reservoir. Weirs will be constructed along the length of the bioswale such that slopes will not exceed 2%. The underdrain will tie into the existing stormwater system to ensure that flooding is prevented when infiltration capacity is exceeded. The drain rock reservoir will also allow for some infiltration to help with groundwater recharge.

The rational method was used to determine runoff around the underpass, assuming an area of 1953 m3 and runoff coefficient C=0.375. A rainfall intensity value of 48 mm/h was obtained from local IDF curves assuming climate change scenarios. These values give a flow of 0.01 m3/s. Assuming a velocity of 1 m/s, a pipe diameter of 200 mm is required. Three lawn basins with 150 mm leads at a 1% slope will drain to this pipe at a 1% slope, ultimately tying into the main stormwater system.

4. Construction Management

4.1. Construction Specifications

All project construction will be subject to relevant municipal, provincial, and federal standards as follows:

- City of Vancouver Construction and Noise Bylaws
- University of British Columbia Construction and Noise Bylaws
- WorkSafeBC Workers Compensation Act, Occupational Health and Safety Regulations, and Employer and Employee Responsibilities
- CSA Standards for Occupational Health and Safety

All roadworks to conform to the following:

- City of Vancouver Street Design Guidelines and Construction Standards
- MMCD Design Guidelines (As Specified by CoV)
- BC Ministry of Transportation Standard Specifications for Highway Construction
- Transportation Association of Canada Manual of Uniform Control Devices for Canada

All structural concrete construction for pedestrian underpass is to abide by:

- CSA A23.3-14 Design of Concrete Structures 2014

In general, construction will adhere to the 2016 MOTI Standards for Highway Construction. Specific cases from this document are detailed in Appendix C.

4.2. Construction Sequencing

1) Site fencing installed
2) Clear/grub grass from median; windrow organic soils on median
3) Remove existing intersection

4) Install roundabout
    a) Issues - the intersection must be closed while the center island is being built or there must be a diversion
5) While the roundabout is under construction, remove the north lanes and existing drainage infrastructure
6) Mill and grind the asphalt for recycling from the north lanes
7) Excavate down to finished grade on north lanes
8) Stockpile material from north lanes adjacent to fill area around the pedestrian underpass
9) Prepare base and pave the north lanes
10) Mill and grind the asphalt for recycling from the south lanes
11) Stockpile material
12) Excavate down to finished grade on south lanes, in bioswale region,
13) At this point in the construction, two features will be built concurrently: the bioswale and the pedestrian underpass
14) Pedestrian Underpass:
    a) Build temporary diversion road around pedestrian underpass
    b) Construct Cast-In-Place Footings
        i) Excavate to foundation base and compact
        ii) Assemble formwork for strip footings
        iii) Assemble and place reinforcement cages
        iv) Pour concrete footings
    c) Construct Cast-In-Place Walls
    d) Construct Cast-In-Place Slab on Grade
    e) Construct Cast In Place Slab (upper)
    f) Backfill and build MSE wall around cast-in-place tunnel
    g) Pave road over pedestrian underpass
    h) Dismantle temporary road
    i) Construct drainage system for underpass
15) Bioswale:
    a) Excavate trench
    b) Install drain rock reservoir and drain pipe

  c) Tie into existing drainage system
  d) Install topsoil
  e) Sod and landscaping/gardening
  f) Install weirs

16) Install multi-use path
17) Landscaping and hydroseeding along sides of roads

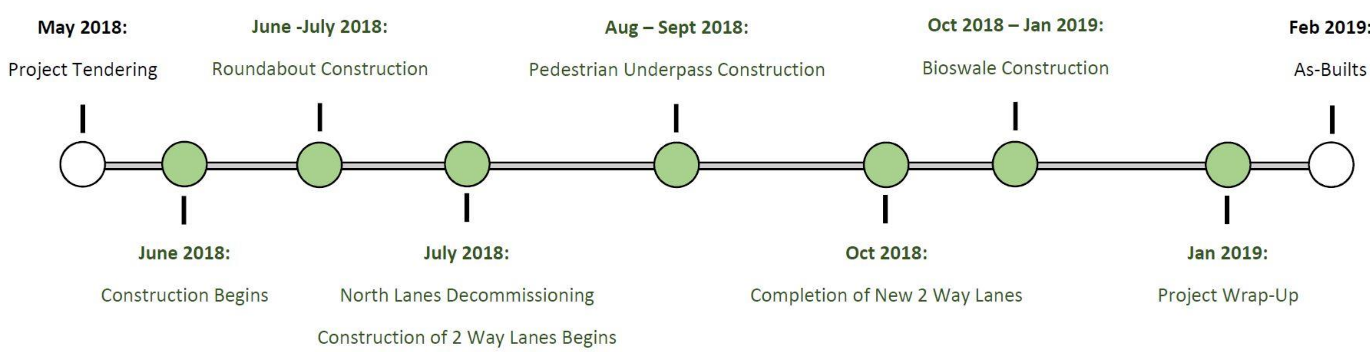

Figure 4-1 Schematic Construction Schedule

Please see Detailed Construction Schedule in Appendix D.

4.3. Anticipated Issues

1) Traffic management will be an ongoing concern, more acute at some points in construction. Traffic will be most impacted during the construction of the pedestrian underpass, when it will be rerouted around the fill area on one lane and controlled by flaggers.
   a) Solution: Traffic impacts may be mitigated if the construction schedule is shifted such that the pedestrian underpass is constructed during the summer, while classes are not in session.
2) While the road is being constructed near University Hill Elementary School the existing pedestrian crossing will be gone.
   a) A temporary crossing will need to be provided for local pedestrians and students attending University Hill Elementary School. Coordination between construction flaggers and school staff should take place in order to ensure that the needs of the elementary school students and staff are met.
3) High Rainstorm event, delaying excavations and causing erosion of earth works

   a) Ensure earthworks and fill are compacted to acceptable standards to maintain soil integrity, avoid heavy machinery on compacted soils during rain events and provide adequate stormwater management on site to mitigated ponding
4) Jaywalking through the construction site
   a) Fencing will be installed around active construction areas to ensure that people do not cross into construction areas. Outside of the construction areas, existing crossings will be left in place until improvements are built
5) There will be many different kinds of material being excavated that should not be mixed together
   a) Separate stockpiles will be maintained for milled asphalt, organic soil, and inorganic fill
6) The roundabout will not be usable with the island is being constructed. The road will have to be closed at this point
   a) Signs should be put at each end of the corridor warning road users that a detour to 10th ave is necessary for access to the university
7) The bioswale, especially the topsoil portion, will be extraordinarily vulnerable to sediments transported by water. Water is directed to the bioswales by gravity. When functioning under ordinary circumstances, water percolates down through the pores in the topsoil and infiltrates below. When the water is carrying high loads of sediment, a condition that occurs to a great extent during construction, the sediment will clog the pore spaces and reduce the hydraulic conductivity of the soil, making infiltration slower. This will greatly reduce the effectiveness of the bioswale
   a) Very careful erosion and sediment measures should be taken during construction to prevent excessive sediment from entering the bioswale. Just as in any construction site, sediment barriers should be placed at entrances to the bioswale to filter incoming runoff.

4.4. Construction Cost

The total anticipated cost for the project is $3.85 Million. Please see Appendix E for a detailed cost breakdown.

5. Operations and Maintenance

The operations and maintenance required for the corridor has been divided into two main categories, "Minor" and "Major", respectively. Minor O & M includes all tasks that maintain the current operation and design of the main roadway and other aspects of the corridor and are required on an annual or near-annual basis while Major O &M tasks are those which require significant reconstruction of the corridor.

As UBC's future needs for the Chancellor Boulevard Corridor may change, we have chosen to forecast operations and maintenance for a 20-year period as this is approximately when major repairs will need to be made, thus affording an opportunity to address new demands and industry practice into the corridor at such time. Additionally, Campus Consulting cannot reasonably attempt to forecast operations and maintenance costs beyond such time line.

We anticipate the corridor to have a useful life far greater than 20 years and believe that the design will meet the needs of our client well into the future. The corridor can be expected to function indefinitely so long as UBC and the City of Vancouver feel that the cost-benefit analysis of its use is returning satisfactory results.

5.1. Minor Operations and Maintenance

As with most large infrastructure projects, more significant repairs such as minor road surface repair will tend to increase in frequency as the corridor ages. We acknowledged that these items may occur several times over our initial lifespan projection of 20 years, however, to simplify our estimates we have considered them to occur on a linear basis and amortized these costs into average annual costs so that they may be added to the other operational costs to create a total average annual cost per year.

The following table below outlines all tasks we believed to be of "Minor" status:

Table 5-1 Minor Operations and Maintenance Line Items

Item	Applies to	Work Done By	Occurrence
Tree and Brush Pruning and Removal	Corridor	Metro Van (Parks)	Annual
Trash/Litter Removal	Bioswale	Metro Van (Parks)	Quarterly
Landscaping	Bioswale	Metro Van (Parks	Annual
Seasonal Check and Cleaning of Road Signs	Corridor	Metro Van (Parks)	Annual
Reseeding and Fertilizing	Corridor	Metro Van (Parks	Annual
Centerline Re-Painting	Road	MoT (Contractor)	Every 2 Years
All Other Lines	Road	MoT (Contractor)	Every 5 Years
Crack Sealing	Road	MoT (Contractor)	5 Times in 20 Years
Patching	Road	MoT (Contractor)	5 Times in 20 Years
Pothole Filling	Road	MoT (Contractor)	3 Times in 20 Years
Structural Inspection	Underpass	MoT (Contractor)	Annual
Lighting Replacement and Maintenance	Underpass	MoT (Contractor)	Every 5 Years
Road De-Icing & Snow Plowing	Road	CoV	6 Months of Year
Delineator Replacement	Road	CoV	Bi-Annual
Mowing	Corridor	Metro Van (Parks	Seasonally & Monthly in Summer
Weed Control	Corridor	Metro Van (Parks	Seasonally & Monthly in Summer
Culvert (x2) Inspection and Cleaning	Drainage	MoT (Contractor)	Annual
Storm Sewer Inspection and Cleaning	Drainage	MoT (Contractor)	Every 5 Years
Mutli-Use Path Repairs	Corridor	CoV	Every 5 Years

We estimate Minor O&M to be account for a total average annual cost of $161,500 2018 Canadian Dollars. Using a nominal inflation rate of 3%, we have forecasted these costs for the first 20 years of the corridors service in the table below.

Table 5-2 Minor Operations and Maintenance Costs

	2020	2024	2029	2034	2039
Service Year:	1	5	10	15	20
Cost:	$171,335	$192,839	$223,554	$259,160	$300,438

5.2. Major Operations and Maintenance

Major Operations and Maintenance are summarized as the larger construction repair and redesign work required on a non-frequent occurrence as compared to tasks associated with Minor O&M. Campus consulting has identified the tasks deemed to be Major in the following table.

Table 5-3 Major Operations and Maintenance Line Items

Item	Applies to	Work Done By	Occurrence
Road Resurfacing and Reshaping	Road	MoT (Contractor)	Every 20 Years
Curb and Gutter Repair	Road & Drainage	MoT (Contractor)	Every 20 Years

We have estimated the total cost for Major O&M to be $1,000,000 2018 Canadian Dollars. Using a nominal inflation rate of 3% we have forecasted the first projected occurrence of Major O&M to have cost of $1,860,295 in 2039 Canadian Dollars.

6. Conclusion

Campus Consulting was retained to complete a detailed redesign of the Chancellor Boulevard corridor. The objectives governing the redesign process include:

- meeting all future transportation demands,
- prioritizing buses, cyclists, and pedestrians and ensuring the safety of all road users,
- avoiding negatively impacting Pacific Spirit Park and the habitats it provides,
- accommodating and improving drainage, and
- minimizing costs and optimizing the construction schedule.

Pursuant to these goals, the Campus Consulting project team has created a detailed design including features such as a pedestrian underpass and vehicle roundabout at the Hamber Road intersection, marked pedestrian crosswalks with beacons at all pedestrian crossings, a multi-use path made of permeable pavement, narrowed vehicle travel lanes, and dedicated bicycle lanes.

The design is unique it that it will include a large infiltration swale, reducing the quantity and improving the quality of road runoff; it has a separated multi-use path, allowing pedestrians some measure of segregation from motorized vehicles; it removes the median between vehicle travel lanes, slowing traffic; and construction sequencing has been planned to be the least disruptive to the surrounding neighborhood as the road can be built independently of the infiltration swale, minimizing the constriction of traffic. Stakeholders have been involved throughout the entire design process and will continue to be involved in this landmark project as it proceeds.

7. Software & References

7.1. Software

7.1.1. Civil3D

Civil3D is a civil engineering modelling and drafting program produced by Autodesk. It was used to produce the design drawings as well as determine quantities for the construction pricing and schedule.

7.1.2. PCSWMM

Stormwater modeling on this project was performed with PCSWMM. This program allowed us to accurately delineate Chancellor Boulevard as a set of catchments, and also to model outfalls for each catchment. Also, the program allowed us to input historical long-term precipitation data as well as create a design storm in order to test short and long-term outflow. Further to this, PCSWMM allows the user to model sites with Low Impact Development features. In the case of this project, it allowed us to model the site with and without infiltration swales in order to verify that the infiltration swale design created using Metro Vancouver's Stormwater Source Control Guideline performs as expected.

7.1.3. ETCulvert

The culvert segments were designed in software using "ETCulvert" which was created by Eriksson Software located in Tampa, Florida. The program allows for fully automatic design and analysis of both 3-sided and 4-sided culverts. It incorporates design standards from AASHTO and LRFD/LRFR specifications. The program is flexible in design allowing for input of many design parameter inputs and updates the design as parameters are changed. It is a fast-efficient program that provides a comprehensive rebar or WWF (mesh) schedule and rebar layout which can be printed and used as drawing to construct the culvert segments. Also, the program is capable of producing renderings of your design, which gives a visual representation of the rebar cage within the concrete structure.

7.1.4. Synchro 6 plus SimTraffic

Synchro is a traffic planning and analysis software produced by Trafficware which is capable of modelling and analyzing street networks. Input data in the form of traffic volume, traffic content, and peak hour factors are required to be determined prior to modelling using Synchro. Campus Consulting used Synchro to analyze potential intersection options for Chancellor Boulevard and Hamber Road.

7.1.5. Sidra Intersection 7.0

Similar to Synchro, Sidra is a traffic analysis software that models traffic networks based and is developed by Sidra Solutions. Upon acquiring base input data, users may specify intersection details and determine service outputs. Campus Consulting used Sidra specifically for modelling a roundabout at the intersection of Chancellor Boulevard and Hamber Road as it is considered by industry to provides better results and accuracy than Synchro for these types of intersection.

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Appendix A: Species List

English Name	Global Status	Prov Status	COSEWIC	BC List	SARA	General Status Canada	Name Category	Class (English)	Kingdom	Regional Dist
Great Blue Heron, Fannini Subspecies	G5T4	S2S3B,S4N	SC (Mar 2008)	Blue	1-SC (Feb 2010)		Vertebrate Animal	birds	Animalia	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;SLRD;CBRD;MWRD;CCRD;SQCRD;KSRD;FVRD
Vancouver Island Beggarticks	G3	S3	SC (Nov 2001)	Blue	1-SC (Jun 2003)	3 - Sensitive (2010)	Vascular Plant	dicots	Plantae	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;SLRD;CCRD;FVRD
Marbled Murrelet	G3	S3B,S3N	T (May 2012)	Blue	1-T (Jun 2003)	1 - At Risk (2005)	Vertebrate Animal	birds	Animalia	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;SLRD;MWRD;CCRD;SQCRD;KSRD;FVRD
Western Screech-owl, Kennicottii Subspecies	G5T4	S2S3	T (May 2012)	Blue	1-SC (Jan 2005)		Vertebrate Animal	birds	Animalia	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;SLRD;MWRD;CCRD;SQCRD;KSRD;SKRD;FVRD
Band-tailed Pigeon	G4	S3S4B	SC (Nov 2008)	Blue	1-SC (Feb 2011)	3 - Sensitive (2005)	Vertebrate Animal	birds	Animalia	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;SLRD;TNRD;MWRD;CCRD;SQCRD;KSRD;FVRD
Northern Red-legged Frog	G4	S3	SC (May 2015)	Blue	1-SC (Jan 2005)	3 - Sensitive (2005)	Vertebrate Animal	amphib	Animalia	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;SLRD;MWRD;CCRD;SQCRD;FVRD
Twisted Oak Moss	GNR	S3	SC (Nov 2014)	Blue	1-SC (Jul 2005)		Nonvasc. Plant		Plantae	MVRD;CRD;CVRD;RDN
Green Sturgeon	G3	S1N	SC (Nov 2013)	Red	1-SC (Aug 2006)	2 - May be at risk (2005)	Vertebrate Animal	ray-finned fishes	Animalia	MVRD;SLRD;SQCRD;KSRD;SKRD
Western Pond Turtle	G3G4	SX	XT (May 2012)	Red	1-XX (Jan 2005)	.2 - Extinct (2005)	Vertebrate Animal	turtles	Animalia	MVRD;FVRD
Oregon Forestsnail	G3G4	S2	E (Apr 2013)	Red	1-E (Jan 2005)		Invertebrate Animal	gastropods	Animalia	MVRD;FVRD
Salish Sucker	G1	S1	T (Nov 2012)	Red	1-E (Jan 2005)	1 - At Risk (2000)	Vertebrate Animal	ray-finned fishes	Animalia	MVRD;FVRD
Painted Turtle - Pacific Coast Population	G5T2	S2	T (Nov 2016)	Red	1-E (Dec 2007)		Vertebrate Animal	turtles	Animalia	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;FVRD
Puget Oregonian	G3	SX	XT (Apr 2013)	Red	1-XX (Jan 2005)		Invertebrate Animal	gastropods	Animalia	MVRD;CRD;FVRD

Dun Skipper	G5	S2	T (Apr 2013)	Red	1-T (Jun 2003)	6 - Not Assessed (2000)	Invertebrate Animal	insects	Animalia	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SLRD;TNRD;FVRD
Northern Abalone	G3G4	S2	E (Apr 2009)	Red	1-E		Invertebrate Animal	gastropods	Animalia	MVRD;CRD;CVRD;RDN;ACRD;CXRD;STRD;PWRD;SCRD;MWRD;CCRD;SQCRD;KSRD;SKRD
Streambank Lupine	G2G4	S1	E (Nov 2002)	Red	1-E (Jan 2005)	1 - At Risk (2010)	Vascular Plant	dicots	Plantae	MVRD;CRD
Greenish Blue, Insulanus Subspecies	G5TH	SH	E (May 2012)	Red	1-E (Jun 2003)		Invertebrate Animal	insects	Animalia	MVRD;CRD;CVRD;RDN;CXRD
Oregon Spotted Frog	G2	S1	E (May 2011)	Red	1-E (Jun 2003)	1 - At Risk (2005)	Vertebrate Animal	amphibians	Animalia	MVRD;FVRD
Nooksack Dace	G3	S1	E (Apr 2007)	Red	1-E (Jun 2003)	1 - At Risk (2000)	Vertebrate Animal	ray-finned fishes	Animalia	MVRD;FVRD
Pacific Water Shrew	G4	S2?	E (Apr 2016)	Red	1-E (Jun 2003)	1 - At Risk (2005)	Vertebrate Animal	mammals	Animalia	MVRD;SLRD;FVRD
Spotted Owl	G3G4	S1	E (Mar 2008)	Red	1-E (Jun 2003)	1 - At Risk (2005)	Vertebrate Animal	birds	Animalia	MVRD;SLRD;TNRD;OSRD;FVRD
Barn Owl	G5	S2?	T (Nov 2010)	Red	1-SC (Jun 2003)	3 - Sensitive (2005)	Vertebrate Animal	birds	Animalia	MVRD;CRD;CVRD;RDN;CXRD;STRD;NORD;CSRD;OSRD;FVRD
Mountain Beaver	G5	S4	SC (May 2012)	Yellow	1-SC (Jun 2003)	4 - Secure (2005)	Vertebrate Animal	mammals	Animalia	MVRD;TNRD;OSRD;FVRD
Coastal Tailed Frog	G4	S4	SC (Nov 2011)	Yellow	1-SC (Jun 2003)	3 - Sensitive (2005)	Vertebrate Animal	amphibians	Animalia	MVRD;STRD;PWRD;SCRD;SLRD;TNRD;MWRD;CCRD;SQCRD;KSRD;OSRD;FVRD

Appendix B: Underpass Sample Calculations

Table B-1 – Constants and Assumptions for Underpass Loading, Structural Design

	f_c'=	30	Mpa
	f_y =	400	MPa
	height =	2.5	m
	span =	4.5	m
	ϕ_c =	0.65	
	ϕ_s =	0.85	
Truck Tire	w =	0.6	m
	l =	0.25	m
Unfactored	P =	87.5	kN
	s =	1.8	m
	α_1 =	0.8	
Assume pin-pin	k =	1	

Table B-2 – Axial Loads on Concrete Retaining Wall

	D	E	P	L*	K	W	V	S	EQ	F	A	H
LOADS (kN)	23.12	0	0	97.22	0	0	0	4.95	0	0	0	0

Per Table 3.1, CSA S6-06

		PERMANENT LOADS			TRANSITORY LOADS					EXCEPTIONAL LOADS				
	Loads	D	E	P	L*	K	W	V	S	EQ	F	A	H	**TOTAL**
Fatigue Limit State	FLS1	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	120.34
Serviceability Limit States	SLS1	1.00	1.00	1.00	0.90	0.80	0.00	0.00	1.00	0.00	0.00	0.00	0.00	115.57
	SLS2	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.50
Ultimate Limit States	ULS1	1.20	1.25	1.05	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	193.02
	ULS2	1.20	1.25	1.05	1.60	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	183.30
	ULS3	1.20	1.25	1.05	1.40	1.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	163.85
	ULS4	1.20	1.25	1.05	0.00	1.25	1.65	0.00	0.00	0.00	0.00	0.00	0.00	27.74
	ULS5	1.25	1.25	1.05	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	28.90
	ULS6	1.20	1.25	1.05	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	27.74
	ULS7	1.20	1.25	1.05	0.00	0.00	0.90	0.00	0.00	0.00	0.00	1.30	0.00	27.74
	ULS8	1.20	1.25	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	27.74
	ULS9	1.35	1.25	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.21

Table B-3 – Lateral earth loads on the retaining wall

	D	E	P	L*	K	W	V	S	EQ	F	A	H
LOADS (kN)	0	11.875	0	15.20	0	0	0	0	0	0	0	0

Per Table 3.1, CSA S6-06

		PERMANENT LOADS			TRANSITORY LOADS					EXCEPTIONAL LOADS				
	Loads	D	E	P	L*	K	W	V	S	EQ	F	A	H	**TOTAL**
Fatigue Limit State	FLS1	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.08
Serviceability Limit States	SLS1	1.00	1.00	1.00	0.90	0.80	0.00	0.00	1.00	0.00	0.00	0.00	0.00	25.56
	SLS2	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.68
Ultimate Limit States	ULS1	1.20	1.25	1.05	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.68
	ULS2	1.20	1.25	1.05	1.60	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.16
	ULS3	1.20	1.25	1.05	1.40	1.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	36.12
	ULS4	1.20	1.25	1.05	0.00	1.25	1.65	0.00	0.00	0.00	0.00	0.00	0.00	14.84
	ULS5	1.25	1.25	1.05	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	14.84
	ULS6	1.20	1.25	1.05	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	14.84
	ULS7	1.20	1.25	1.05	0.00	0.00	0.90	0.00	0.00	0.00	0.00	1.30	0.00	14.84
	ULS8	1.20	1.25	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.84
	ULS9	1.35	1.25	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.84

Calculation of the wall resistance and dimensions under axial loads

Bearing Wall Axial Load Calculations

1. Min Thickness	$t =$	0.12	m			
2. Bearing Strength	$B_r =$	1193.4	kN	Greater than a tire load and dead load		
3. Factored Axial Load Resistance	$l_b <$	2.76	m	<	1.8	m
	$l_b =$	1	m	(assume UDL)		
	$A_g =$	0.12	m^2			
	$P_r =$	**486.28**	**kN/m**	Resistance greater than load		
	$P_f =$	193.02	kN/m			
4. Determine min reinf.	$A_g =$	12000 0	mm^2			
Horizontal reinf.	$A_{h,min} =$	240	mm^2/m			

	Assume 15M rebar		$s =$		833.33 33	mm	
$d_b =$	15	mm					
$A_b =$	200	mm^2	$s_{,max} = ?$	=		0.36	m
						0.5	m
	HORIZONTAL SPACING		$s_{,max} =$		0.36	m	
			$A_h =$		556	mm^2/m	
Vertical reinf.			$A_{v,min} =$		180	mm^2/m	
	Assume 15M rebar		$s =$		1111	mm	
$d_b =$	15	mm					
$A_b =$	200	mm^2	$s_{,max} = ?$	=		0.36	m
						0.5	m
	VERTICAL SPACING		$s_{,max} =$		0.36	m	

A_v = 556 mm^2/m

Wall Axial Load Calculations Summary:

- Use 15M rebar for both vertical and horizontal reinforcement spaced at 300mm in both directions (NEED VERTS AT 150MM, SEE FOLLOWING)
- Wall is 120mm thick

Calculation of the Wall Resistance and Dimensions Under Flexural Loads

Flexural Steel (vertical)

		thickness	t =		0.12	m
	15M rebar		d =		93	mm
d_b =	15	mm				
A_b =	200	mm^2	$A_{s,req}$ =		1151	mm2/m
			s <		174	mm
			Choose s =		150	mm
Proper reinforcement?			A_s =		1333.333	mm^2/m
			ρ =		0.014414	

Wall Flexural Load Calculations Summary:

- Use 15M reinforcement, vertical rebar to be spaced at 150mm

MSE Wall Calculations

radius =	3	m	FS_{ID} =	1.5
load =	149	kN	FS_{CR} =	2
ϒ =	18	kN/m^3	FS_{CD} =	1.3
$Ø_{cs}$ =	30	deg	FS_{BD} =	1.3
$Ø_{cs}$ =	0.52	rad	FS_{SP} =	1.3
$Ø_b$ =	20	deg	FS_T =	1.3
$Ø_b$ =	0.35	rad		
Fail Angle	60	deg		
K_{ar} =	0.33			
T_{ult} =	58.6	kN		
T_{all} =	11.56	kN		
Sz_{min} =	0.48	m		
K_{ac} =	0.30			
S_u =	60.00	kPa		
S_W =	30.00	kPa		
L_b =	1.80	m		
L_b =	2.17	m		
USE L_b =	2.17	m		

Table B-4- MSE Wall Dimensions

depth (m)	σ (kPa)	Δσ (kPa)	total σ (kPa)	lat σ (kPa)	max S_z (m)	Actual S_z	lat P (kN)	L_r (m)	L_e (m)	L (m)	Actual L (m)
0.00	0.00	0.00	0.00	0.00	1481818.64	0.8		2.1	0.30	2.4	2.5
0.2	3.6	0.00	3.60	1.20	7.40	0.8	0.21	2.0	0.30	2.3	2.5
0.4	7.2	0.02	7.22	2.41	3.70	0.8	0.43	1.9	0.30	2.2	2.5
0.6	10.8	0.06	10.86	3.62	2.46	0.8	0.65	1.8	0.30	2.1	2.5
0.8	14.4	0.13	14.53	4.84	1.84	0.8	0.86	1.7	0.30	2.0	2.5
1	18	0.22	18.22	6.07	1.46	0.8	1.08	1.6	0.30	1.9	2.5
1.2	21.6	0.35	21.95	7.32	1.22	0.8	1.31	1.5	0.30	1.8	2.5
1.4	25.2	0.49	25.69	8.56	1.04	0.8	1.53	1.3	0.30	1.6	2.5
1.6	28.8	0.64	29.44	9.81	0.91	0.8	1.75	1.2	0.30	1.5	2.5
1.8	32.4	0.79	33.19	11.06	0.80	0.4	1.97	1.1	0.15	1.3	2.5
2	36	0.93	36.93	12.31	0.72	0.4	2.20	1.0	0.15	1.1	2.5
2.2	39.6	1.06	40.66	13.55	0.66	0.4	2.42	0.9	0.15	1.0	2.5
2.4	43.2	1.17	44.37	14.79	0.60	0.4	2.64	0.8	0.15	0.9	2.5
2.6	46.8	1.27	48.07	16.02	0.55	0.4	2.86	0.6	0.15	0.8	2.5
2.8	50.4	1.34	51.74	17.25	0.52	0.4	3.08	0.5	0.15	0.7	2.5
3	54	1.40	55.40	18.47	0.48	0.4	3.29	0.4	0.15	0.6	2.5
3.2	57.6	1.43	59.03	19.68	0.45	0.4	3.51	0.3	0.15	0.5	2.5
3.4	61.2	1.46	62.66	20.89	0.43	0.4	3.73	0.2	0.15	0.3	2.5
3.6	64.8	1.47	66.27	22.09	0.40	0.2	3.94	0.1	0.08	0.1	2.5
3.8	68.4	1.47	69.87	23.29	0.38	0.2	4.15	0.0	0.08	0.0	2.5
						P_{ax} =	41.6	kN/m			

FS against bearing failure

TSA

q_u =	308.4	kPa
FS_B =	4.51	

ESA

horizontal	41.61	kN/m
vertical	135	kN/m
ω	17.13	deg
n =	2	
i_γ =	0.33	
N_γ =	22.46	
q_u =	171.96	
FS_B =	2.46	

FS against overturning

Lat Pressure Force	43.3	kN/m
Lat Moment Arm	1.266667	m
MSE Section Weight	171	kN/m
Weight Moment Arm	1.25	m
FS_o =	3.9	

Calculation of Roof Slab Design Strip:

1. Input Loads		M_f =	180	kN m
		V_f =	185	kN
2. Minimum Thickness		h =	225	mm
	USE:	h =	250	mm
3. Shear Design		d =	185	mm
		d_v =	167	mm
		β =	0.197	
		V_c =	117.1	kN
V_c	<	V_f	*Stirrups Required	
		V_s Req =	68	kN
Assuming 10M Stirrups:				
		Av =	200	mm
		s =	238	mm
	USE:	s =	200	mm
		Smax =	117	mm
	USE:	s =	100	mm
		Av Min =	82	mm
		V_s =	162	kN
		V_r =	279	kN
V_f	<	V_r	*Good	
		V_r / V_f =	1.51	> 1.20
4. Moment Resistance		Kr =	5.26	

As Req = 3682 mm^2

Select 25M @ 120mm O/C:

As = 4176 mm^2

A_s Req'd < A_s *Good

As Min = 500 mm^2

A_s Min < A_s *Good

5. Transverse Steel As Min = 684.6 mm^2

Select 20M @ 420mm O/C:

As = 714 mm^2

A_s Min < A_s *Good

1m Design Strip Summary:

- Slab to have thickness of 250mm
- Longitudinal Rebar to be 25M @ 120mm o/c
- Transverse Rebar to be 20M @ 420mm o/c
- Stirrups in Longitudinal Direction to be 10M @ 100mm o/c

Appendix C: 2016 MOTI Standards for Highway Construction Specifications

Concrete:

1. The contractor shall comply with the standards listed below and be responsible for quality control of all components of the concrete operation, including but not limited to, aggregate and component quality, proportioning, test batching, batching, mixing, transporting, placing, consolidating, finishing, curing, and all necessary quality control and verification testing of the components and the fresh and hardened concrete.

2. The Contractor shall be responsible for proportioning and designing all concrete in full
compliance with the concrete mix parameters as listed in the 2016 MOTI 2016 Standards for Highway Construction. All mix designs shall use the "Absolute-Volume Method" for mix proportioning.

3. The Contractor shall submit a report outlining the proposed mix design for each classification of concrete to the UBC Campus and Community Planning (the Owner) Representative for review and acceptance at least 2 weeks in advance of when concrete production is scheduled to commence. Acceptance of the mix design by the Owner does not constitute acceptance of the concrete. Acceptance of the concrete will be based on the test results and the performance and quality of the concrete and concrete components placed on the project. No concrete shall be placed prior to receiving the Owner's acceptance of the mix design. Each mix design submittal shall contain the standard components listed in the 2016 MOTI 2016 Standards for Highway Construction.

4. Aggregate gradation shall fall within the envelopes specified in Tables 211-B and 211-C

Table 211-B GRADATION REQUIRMENTS FOR COARSE AGGREGATES

NMSA[(1)] (mm)	Product Size (mm)	Total Passing Each Sieve, Percentage by Mass								
		56mm	40mm	28mm	20mm	14mm	10mm	5mm	2.5mm	1.25mm
40	40-5[(2)]	100	95-100	-	35-70	-	10-30	0-5	-	-
28	28-5[(2)]	-	100	95-100	63-83	30-65	-	0-10	0-5	-
20	20-5	-	-	100	90-100	50-90	25-60	0-10	0-5	-
14	14-5	-	-	-	100	90-100	45-75	0-15	0-5	-
10	10-2.5	-	-	-	-	100	85-100	10-30	0-5	0-5

(1) NMSA – nominal maximum size of course aggregate. Definition: The standard Sieve size opening immediately smaller than the smallest through which all of the aggregate must pass.
(2) To prevent segregation, aggregates that make up the above gradings shall be stockpiled and batched in two or more separate sizes as per CSA A23.1

TABLE 211-C GRADATION REQUIREMENTS FOR FINE AGGREGATES

SIEVE SIZE (mm)	TOTAL CUMULATIVE PASSING EACH SIEVE, PERCENTAGE BY MASS	SIEVE SIZE (mm)	TOTAL CUMULATIVE PASSING EACH SIEVE, PERCENTAGE BY MASS
10	100	0.630	25-65
5	95-100	0.315	10-35
2.5	80-100	0.160	2-10
1.25	50-90		

- All materials shall comply with:
  - CAN/CSA A23.1 Concrete materials and methods of concrete construction
  - CAN/CSA A3000 Cementitious Materials Compendium

- Field tests shall conform to:
  - CAN/CSA A23.2 Test Methods and standard practices for concrete

- Formwork shall be designed and constructed in accordance with:
  - CAN/CSA S269.3 Concrete Formwork

- Lab testing shall adhere to:
  - CAN/CSA A283 Qualification Code for Concrete Testing Laboratories

Earthworks:

- All material testing shall be performed according to the following standards:
  - ASTM C127 Test Method for Density, Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
  - ASTM D422 Standard Method of Particle-Size Analysis of Soils
  - ASTM D698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort
  - ASTM D1140 Test Method for Amount of Material in Soils Finer than the No. 200 Sieve
  - ASTM D4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

- Field compaction testing shall adhere to the following standards (Nuclear Methods preferred):
  - ASTM D1556 Test Method for Density of Soil in Place by the Sand-Cone Method
  - ASTM D2167 Test Method for Density of Soil in Place by the Rubber-Balloon Method
  - ASTM D2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
  - ASTM D3017 Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)

Site Grading:

1. The earth embankment shall be constructed in successive horizontal layers not exceeding 200 mm in loose thickness except that the top 500 mm shall be constructed in layers not exceeding 100 mm in loose thickness. Each layer shall be compacted to minimum 95% of the Standard Proctor Density obtained by the current ASTM D 698, except in the top 300 mm of the embankment, which shall be compacted to minimum 100% of the Standard Proctor Density.

2. No organic soils shall be placed in the embankment. Soils with high moisture content that cannot be compacted to the required density shall not be employed without prior aeration and drying.

3. Borrow shall consist of rut resistant material, with less than 20% passing the 0.075 mm sieve and free of organics, high plasticity clays and other unsuitable materials, obtained from an approved source of supply (e.g. pit or quarry) outside the highway right-of way.

4. Aggregates for surfacing, base, subbase and bridge end fill will be tested in accordance with the tests listed in Table 202-A.

TABLE 202-A: AGGREGATE QUALITY TESTS

Based on ASTM	**Title of Test**
C 136	Sieve Analysis of Fine and Coarse Aggregates
C 117	Wash Test of Aggregates
C 88	Soundness of Aggregate by Use of Magnesium Sulphate.
D 2419	Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate
D 6928	Abrasion Loss by Micro-Deval
D 4318	Plastic Limit Determination
BASED ON MOT	**Title of Test**
SS 202 Appendix 1	Fracture Count on Coarse Aggregate
SS 202 Appendix 2	Petrographic Test

5. All aggregates for surfacing, base, subbase, and bridge end fill shall meet the requirements of Table 202-B.

TABLE 202-B: AGGREGATE PROPERTIES

TEST	Test Result							
	Surfacing Aggregates	Base Course			Subbase Aggregates			Bridge End Fill
	HFSA	25mm	50mm	75mm	SGSB	IGSB	OGSB	BEF
Sand Equivalent	≥ 20	≥ 40	≥ 40	≥ 40	≥ 20	≥ 20	≥ 20	≥ 20
Micro-Deval loss factor	≤ 25%	≤ 25%	≤ 25%	≤ 17%	≤ 30%	≤ 25%	≤ 25%	≤ 30%
Fractured Faces Method "A"	≥ 50[1]	≥ 50[1]	≥ 50[1]	≥ 50[1]	n/a	≥ 50[1]	≥ 50[1]	n/a
Plasticity	≤ 6	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[1]Values are for total sample.

6. Aggregate shall have a gradation that defines a curve (% passing versus log sieve size) with a slope between adjacent sieves, equal or intermediate to the corresponding slopes of the boundary curves defined by the specification. Gradations shall fall within the limits, for the specified classification, shown in Table 202-C.

Table 202-C: Aggregate Gradations

Sieve Size (mm)	Percent Passing (%) Sieve Size													
	Surfacing Aggregate	Base Course									Subbase Aggregates			Bridge End Fill
	HFSA	WGB			IGB			OGB			SGSB	IGSB	OGSB	BEF
		25mm	50mm	75mm	25mm	50mm	75mm	25mm	50mm	75mm				
75	---	---	---	100	---	---	100	---	---	100	100	100	100	100
50	---	---	100	---	---	100	55 - 100	---	100	70 - 100	---	55 - 100	70 - 100	30 - 100
37.5	---	---	80 - 100	60 - 100	---	60 - 100	40 - 80	---	75 - 100	50 - 85	---	40 - 80	50 - 85	---
25	100	100	---	---	100	40 - 75	---	100	---	---	---	---	---	---
19	85 - 100	80 - 100	50 - 100	35 - 80	65 - 100	---	17 - 40	75 - 100	35 - 65	15 - 55	15 - 100	17 - 40	15 - 55	20 - 100
12.5	---	---	---	---		15 - 40	---	---	---	---				
9.5	60 - 85	50 - 85	35 - 75	25 - 60	30 - 70	---	---	30 - 65	5 - 35	---	0 - 100	---	---	---
6.3	---	---	---	---	---	---	---	---	---	0 - 20	---	---	0 - 20	---
4.75	40 - 70	35 - 70	25 - 55	20 - 40	15 - 40	---	---	5 - 30	0 - 15	---	---	---	---	10 - 60
2.36	---	25 - 50	20 - 40	15 - 30	10 - 30	10 - 25	10 - 25	0 - 10	0 - 10	0 - 10	---	10 - 25	0 - 10	---
1.18	20 - 50	15 - 35	15 - 30	10 - 20	---	---	---	---	---	---	---	---	---	6 - 32
0.600	---	---	---	---	---	---	---	---	---	---	0 - 100	---	---	---
0.300	10 - 30	5 - 20	5 - 15	3 - 10	5 - 15	5 - 15	4 - 15	0 - 8	0 - 8	0 - 8	0 - 15	4 - 15	0 - 8	4 - 15
0.075	5 - 15	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5	0 - 5

7. Aggregates for subbase shall be delivered to the roadbed as uniform mixtures and shall be spread in layers without segregation, preferably through an approved aggregate spreader. Granular aggregate shall not be end dumped from trucks in piles on the grade. The Owner may permit spreading from the tailgate of trucks or from centre dump units, provided the Owner is satisfied that the work will be well controlled and segregation will not occur.

8. Immediately following spreading, the material shall be compacted to a minimum 100% of the Standard Proctor Density obtained by the current ASTM D 698.

9. The crushed base course shall be constructed in such a manner that the aggregate is neither segregated, contaminated nor degraded. End dumping will not be permitted. The thickness of the crushed base course shall be substantially uniform and the minimum thickness shall not be less than the nominal thickness shown on the Drawings or ordered by the Owner. If the Contractor is unable to provide adequate manually
operated equipment or workers of sufficient skill to lay the crushed base course aggregate within the tolerances specified, the Owner may require that the Contractor lay the aggregate through an approved electronically controlled spreading machine.

10. Immediately following spreading, the crushed base course aggregate shall be compacted to a minimum 100% of the Standard Proctor Density obtained by the current ASTM D 698.

CULVERTS

1. The embedment material shall be placed and compacted in lifts not exceeding 200 mm compacted thickness, with each lift compacted to a minimum of 95% of Standard Proctor Density prior to addition of the next lift. The bedding layer of a 200 mm thickness in direct contact with the invert shall be shaped to the pipe culvert curved invert
   and shall be left uncompacted.

2. The embedment material within 300 mm of the pipe culvert walls shall be free of stones exceeding 75 mm size. Heavy equipment shall not be allowed within 1 m of the pipe culvert walls.

RIPRAP

1. Class 10 riprap shall be used.

2. Rock shall be hard, durable, and angular quarry rock of a quality that will not disintegrate
   on exposure to water or the atmosphere.

3. Riprap shall meet the following quality requirements:

Property	Test Designation	Allowable Value
Specific Gravity	ASTM D6473	≥ 2.60
Absorption	ASTM D6473	≤ 1%
Soundness by use of Magnesium Sulphate	ASTM D5240	≤ 10% (following 5 cycles)
Micro-Deval Abrasion Loss Factor	ASTM D6928	≤ 20%

FENCE

1. Fence shall be of Type D Chain Link Fence
2. Fence materials shall adhere to the following specifications

CAN/CGSB-138.1-M and 1-GP-181M	Fence, Chain Link, Fabric Coating, Zinc-Rich, Organic, Ready Mixed
ASTM A 53	Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
ASTM A 90	Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles
ASTM A 116	Specification for Zinc-Coated (Galvanized) Steel Woven Wire Fence Fabric
ASTM A 121	Specification for Zinc-Coated (Galvanized) Steel Barbed Wire
ASTM A 123	Specification for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel
ASTM A 153	Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A 641	Specification for Zinc-Coated (Galvanized) Carbon Steel Wire
ASTM B 6	Specification for Zinc (Slab Zinc)
ASTM B 211M	Specification for Aluminum-Alloy Bar, Rod, and Wire [Metric]

FOUNDATION EXCAVATION

1. All materials shall be removed as necessary for the construction of foundations or other
works. Foundation excavations shall not be larger than is reasonably necessary. Excavations and adjacent highways and other facilities shall be protected as
necessary by barricades, shoring, dykes and/or cofferdams. Excavations shall be constructed in compliance with the applicable Workers Compensation Act, Occupational Health and Safety Regulations, BC.

2. Care shall be taken not to disturb the bottom of the excavation. If the bottom of the excavation is disturbed in material other than rock, the Contractor shall remove and
dispose of all disturbed material and shall replace it with suitable soil at the direction of the Owner. If the bottom of the excavation is disturbed in rock, the Contractor shall remove and dispose of all disturbed material and shall replace it with a concrete sub-footing, as directed by the Owner.

3. After the structures are sufficiently built, excavations shall be backfilled to the original ground contours with excavated material, as directed by the Owner, unless this material is designated as unsuitable.

4. Drainage course material shall be installed as shown on the Drawings. The gradation of the drainage course materials shall be as follows:

Sieve Size (mm)	% Passing By Mass
40	100
20	0-100
10	0

DESIGN STANDARDS USED:

Reinforced Concrete:
- CSA A23.3-14

Tunnel and loading scheme used for road components:
- CSA S6-06

MSE Wall:
- Canadian Foundation Engineering Manual
- Nilex
- Budhu

Road design:
- NCHRP 672 Roundabouts: An Informational Guide
- BC Supplement to TAC Geometric Guidelines
- NACTO Urban Bikeway Design Guide

Signage:

- BC Ministry of Transportation and Highways Manual of Standard Traffic Signs & Pavement Markings
- Transportation Association of Canada Manual of Uniform Control Devices for Canada

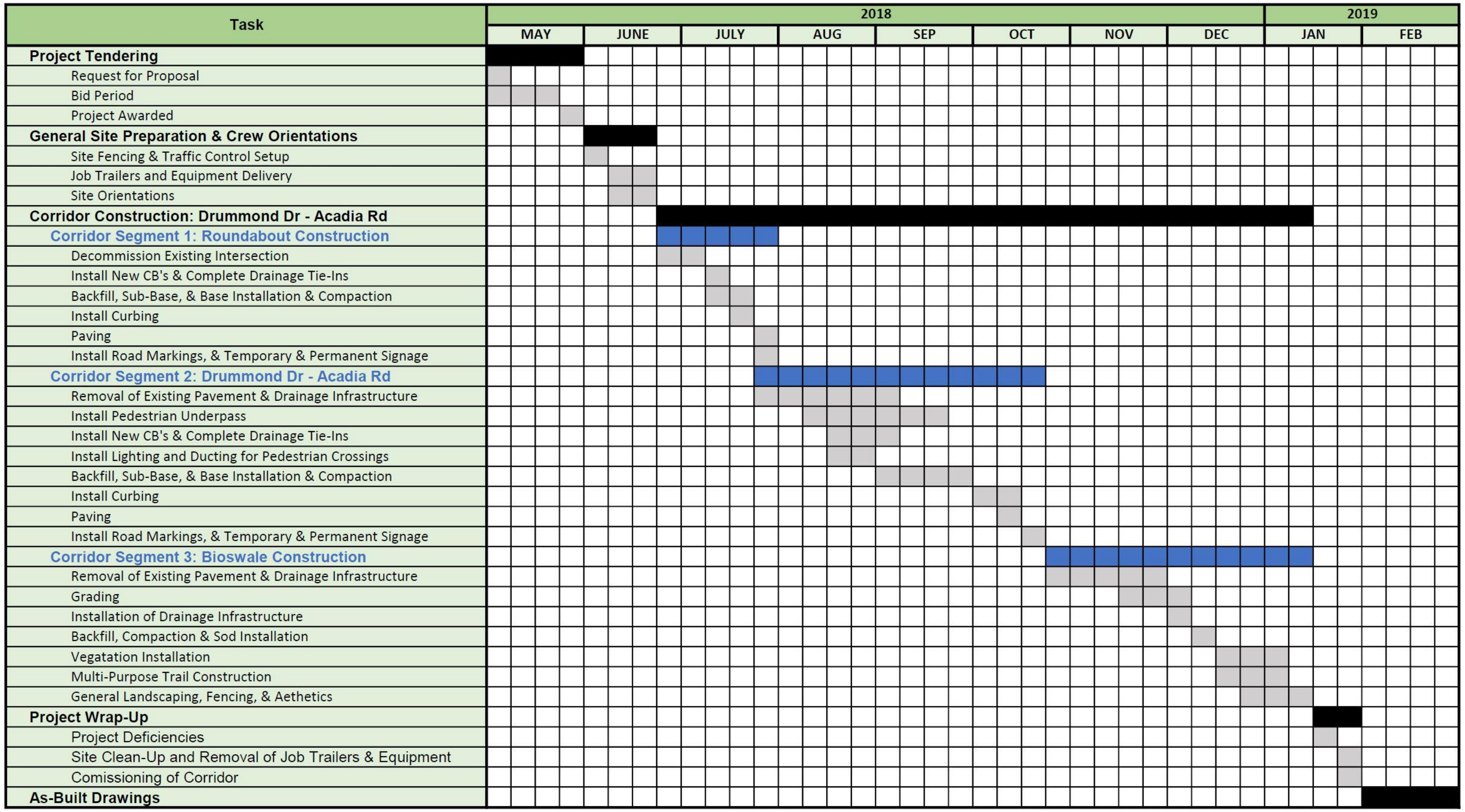
LID:

- Metro Vancouver Stormwater Source Control Design Guidelines 2012

***Design of traditional stormwater infrastructure was performed with the rational method

***Lawn basins typical MMCD

Appendix D: Detailed Design Construction Schedule



Appendix E: Detailed Construction Cost

DESCRIPTION OF WORK	UoM	QTY	Unit Price	Total Amt
DIVISION 01 - GENERAL REQUIREMENTS				
Traffic Control, Vehicle Access and Parking				
Traffic Control, Vehicle Access and Parking - Phase 1 (Roundabout and Underpass)	L.S.	1	$40,000.00	$40,000.00
Traffic Control, Vehicle Access and Parking - Phase 2 (Corridor)	L.S.	1	$10,000.00	$10,000.00
Dynamic Message Signs	Sign / wk	40	$350.00	$14,000.00
Environmental Proteciton				
Environmental Protection - Phase 1	L.S.	1	$30,000.00	$30,000.00
Environmental Protection - Phase 2	L.S.	1	$5,000.00	$5,000.00
Total Division 01				**$99,000.00**
DIVISION 03 - CONCRETE				
Pedestrian Underpass				
Cast-in-Place Construction	Lump Sum	1	$100,000.00	$100,000.00
Concrete Walks, Curb and Gutter				
Barrier Curb and Gutter, MMCD C4	Lineal Metre	3600	$110.00	$396,000.00
Rollover Curb and Gutter, MMCD C4	Lineal Metre	94	$90.00	$8,460.00
1.4.4 Median Curb, SSD-R.15.3 c/w Key	Lineal Metre	100	$70.00	$7,000.00
100mm Thickness, Broom Finished Sidewalk	Square Metre	1050	$100.00	$105,000.00
150mm Thickness, Red stamped concrete	Square Metre	462	$270.00	$124,740.00
Bioswale Weirs	Cubic Metre	7.32	$300.00	$2,196.00
Total Division 03				**$743,396.00**

DIVISION 26 - ELECTRICAL				
Roadway Lighting				
Roadway Lighting for roundabout and tunnel	L.S.	1	$100,000.00	$100,000.00
Total Division 26				**$100,000.00**
DIVISION 31 - EARTHWORK				
Clearing and Grubbing				
Clearing and Grubbing	Lump Sum	1	$50,000.00	$50,000.00
Reshaping Granular Roadbed				
Reshaping Granular Roadbed	Square Metre	10750	$2.25	$24,187.50
Common Excavation				
Common Excavation - Off-Site Disposal	Cubic Metre	12000	$25.00	$300,000.00
Common Excavation - On-Site Reuse	Cubic Metre	5914	$25.00	$147,850.00
Gabions				
Sierra Scape Wall c/w Vegetated Face	Square Metre	740	$400.00	$296,000.00
Rip Rap				
Class 10 Rip Rap (Bioswales)	Tonne	1350	$70.00	$94,500.00
Total Division 31				**$912,537.50**
DIVISION 32 - ROADS AND SITE IMPROVEMENTS				
Cold Milling				
50-75mm Depth (surface) milling	Square Metre	10750	$6.00	$64,500.00
Granular Subbase				
75mm Minus Select Granular Subbase	Tonne	7200	$20.00	$144,000.00
Granular Base				
19mm Minus Granular Base	Tonne	3600	$25.00	$90,000.00

Hot-Mix Asphalt Concrete Paving				
Asphalt Pavement - Lower Course #2	Tonne	1950	$100.00	$195,000.00
Asphalt Pavement - Upper Course #2	Tonne	3890	$110.00	$427,900.00
Porous Asphalt Path, no concrete curb	Square Metre	3,840	$40.00	$153,600.00
Painted Pavement Markings				
Standard Bike and Traffic Lane Markings (≈2km)	Lump Sum	1	$300,000.00	$300,000.00
Permanent Thermoplastic Pavement Markings	Lump Sum	1	$30,000.00	$30,000.00
Enhanced Safety Markings	Lump Sum	1	$10,000.00	$10,000.00
Signage				
BC MoT and CoV Standard Traffic Signs (installed)	ea	40	$500.00	$20,000.00
Fences & Gates				
Cedar Tie Fencing	Lineal Metre	950	$50.00	$47,500.00
1200mm High Steel Handrail MMCD C14, Powder Coated Black, Embedded Mounting in Sidewalk	Lineal Metre	200	$70.00	$14,000.00
Imported Topsoil	Cubic Metre	2884	$40.00	$115,344.00
Hydraulic Seeding				
Hydraulic Seeding	Square Metre	7500	$1.00	$7,500.00
Sodding				
Nursery Sod	Square Metres	4500	$9.00	$40,500.00
Total Division 32				**$1,659,844.00**
DIVISION 33 - UTILITIES				
Storm Sewer				
150mm diameter PVC	Lineal Metre	700	$70.00	$49,000.00
Pipe Culvert				
Concrete Box Culvert (Wildlife Crossing) - 1800mm x 900mm (including natural substrate)	Lineal Metre	22	$3,000.00	$66,000.00
Concrete Box Culvert 4500mm x 2500mm Pedestrian Underpass	Lineal Metre	15	$15,000.00	$225,000.00

Total Division 32				**$340,000.00**

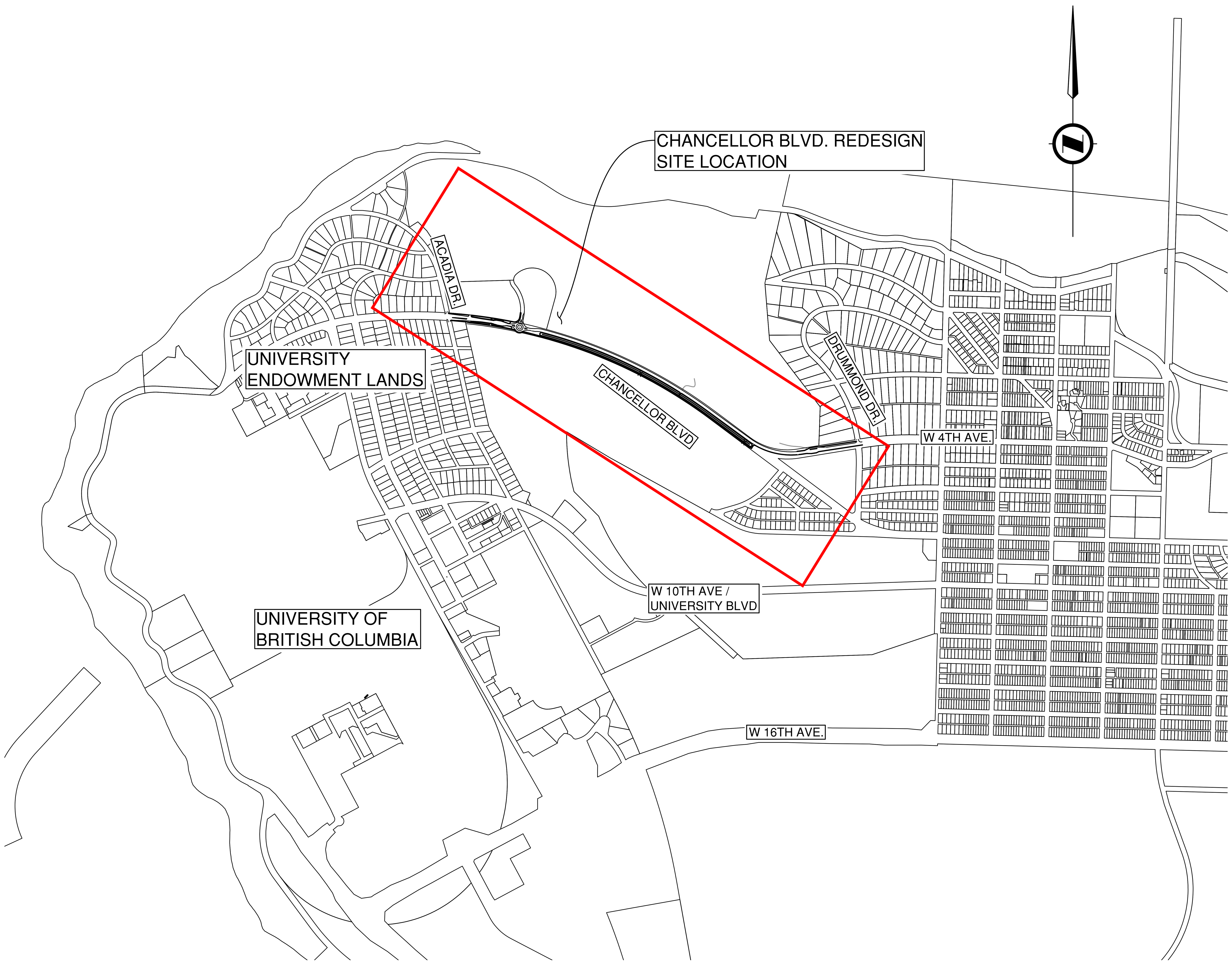
GRAND TOTAL	**$3,854,777.50**

BRITISH COLUMBIA

Ministry of Transportation and Infrastructure

CHANCELLOR BOULEVARD CORRIDOR DETAILED DESIGN

Campus Consulting Ltd.
12324 70th Street, Vancouver, BC



DRAWINGS

- 100-105 PLAN
- 201-203 PROFILE
- 301-302 TYPICAL DETAILS
- 601-604 STORM PLAN & PROFILE
- S-101-103 STRUCTURAL DRAWINGS

SCALE 0 100 1:10,000 500m

CAD FILENAME C0-000
PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
SOUTH COAST REGION
HIGHWAY ENGINEERING AND GEOMATICS

SENIOR DESIGNER
DATE 2017-11-26

DESIGNED BK DATE 2017-11-26
QUALITY CONTROL SM DATE 2017-11-26
QUALITY ASSURANCE CP DATE 2017-11-26
DRAWN BK DATE 2017-11-26

001
CHANCELLOR BOULEVARD
CORRIDOR REDESGN
SITE LOCATION

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER
N/A	N/A	1	C0-000 - 001

SCALE	0 5 1:500 25m	CAD FILENAME C0-100	PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

MINISTRY OF TRANSPORTATION
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SOUTH COAST REGION
HIGHWAY ENGINEERING AND GEOMATICS

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DRAWN	BK	DATE	2017-11-26

101

CHANCELLOR BOULEVARD
PLAN

STA. 0+100.000 TO 0+460.000

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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SCALE 0 5 1:500 25m

CAD FILENAME C0-100

PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

102

CHANCELLOR BOULEVARD
PLAN

STA. 0+460.000 TO 0+820.000

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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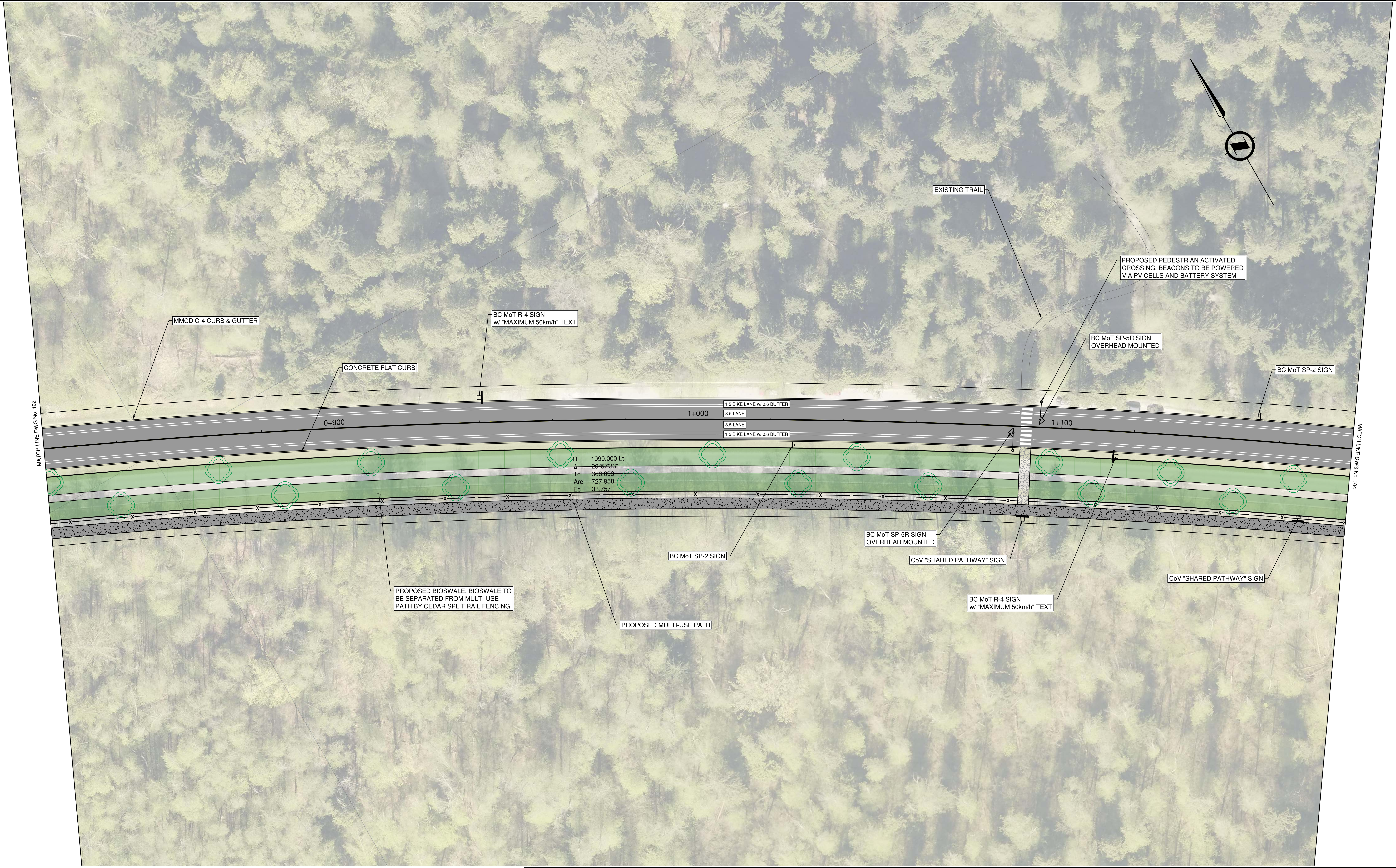

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CAD FILENAME C0-100
PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

103

CHANCELLOR BOULEVARD
PLAN

STA. 0+820.000 TO 1+180.000

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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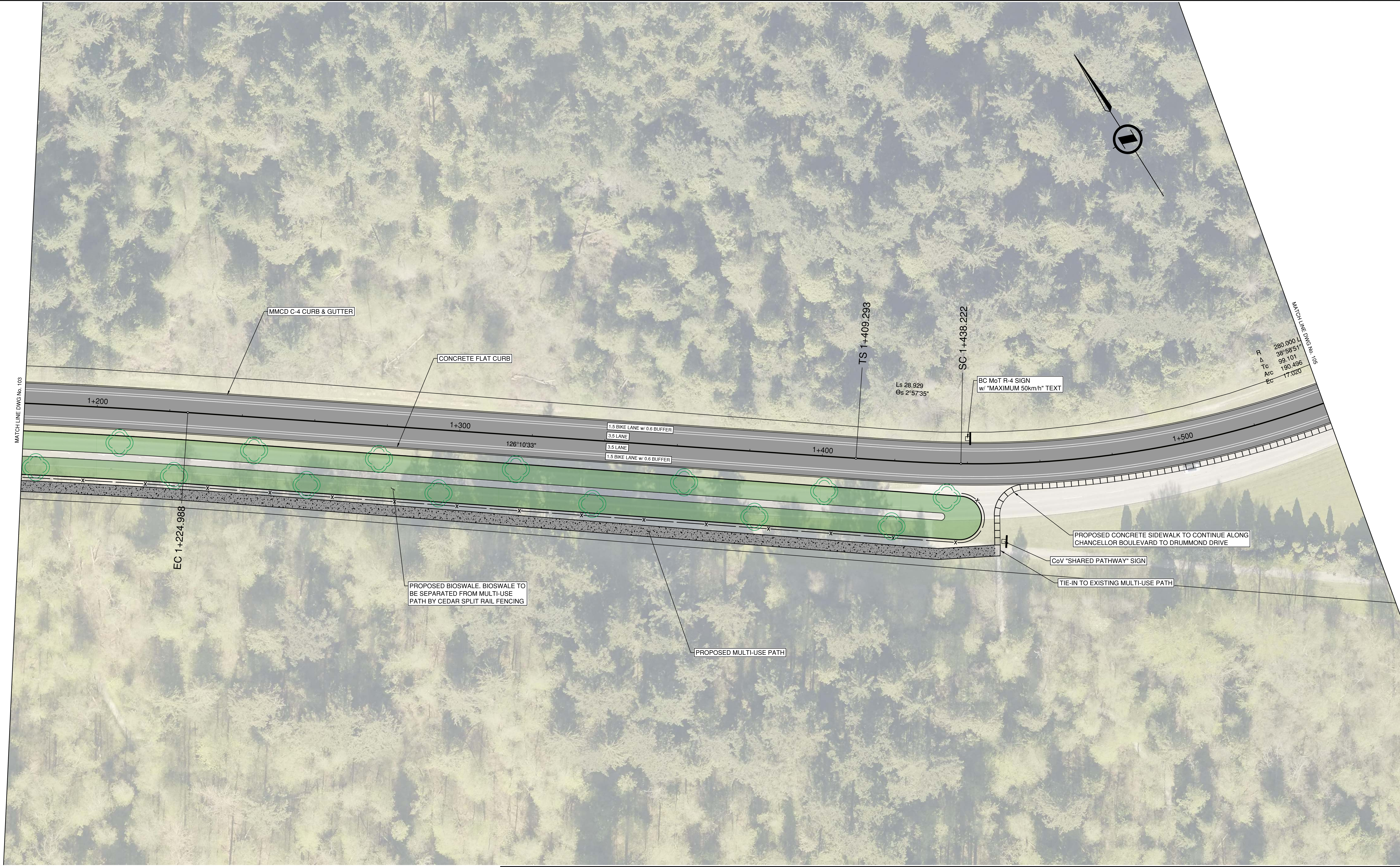

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CAD FILENAME C0-100

PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

MINISTRY OF TRANSPORTATION
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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

104

CHANCELLOR BOULEVARD
PLAN

STA. 1+180.000 TO 1+540.000

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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SCALE	0 5 1:500 25m	CAD FILENAME C0-100	PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

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MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

105

CHANCELLOR BOULEVARD
PLAN

STA. 1+540.000 TO 1+900.000

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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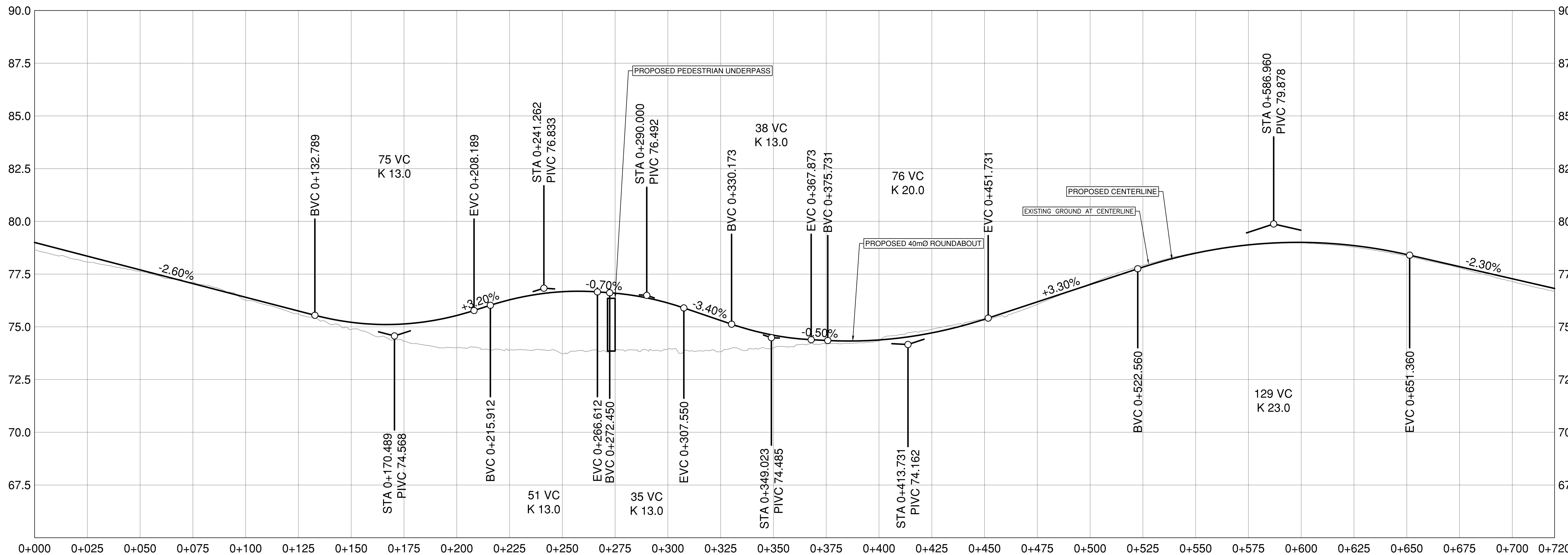

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CAD FILENAME C0-200
PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

201

CHANCELLOR BOULEVARD PROFILE

STA. 0+000.000 TO 0+720.000

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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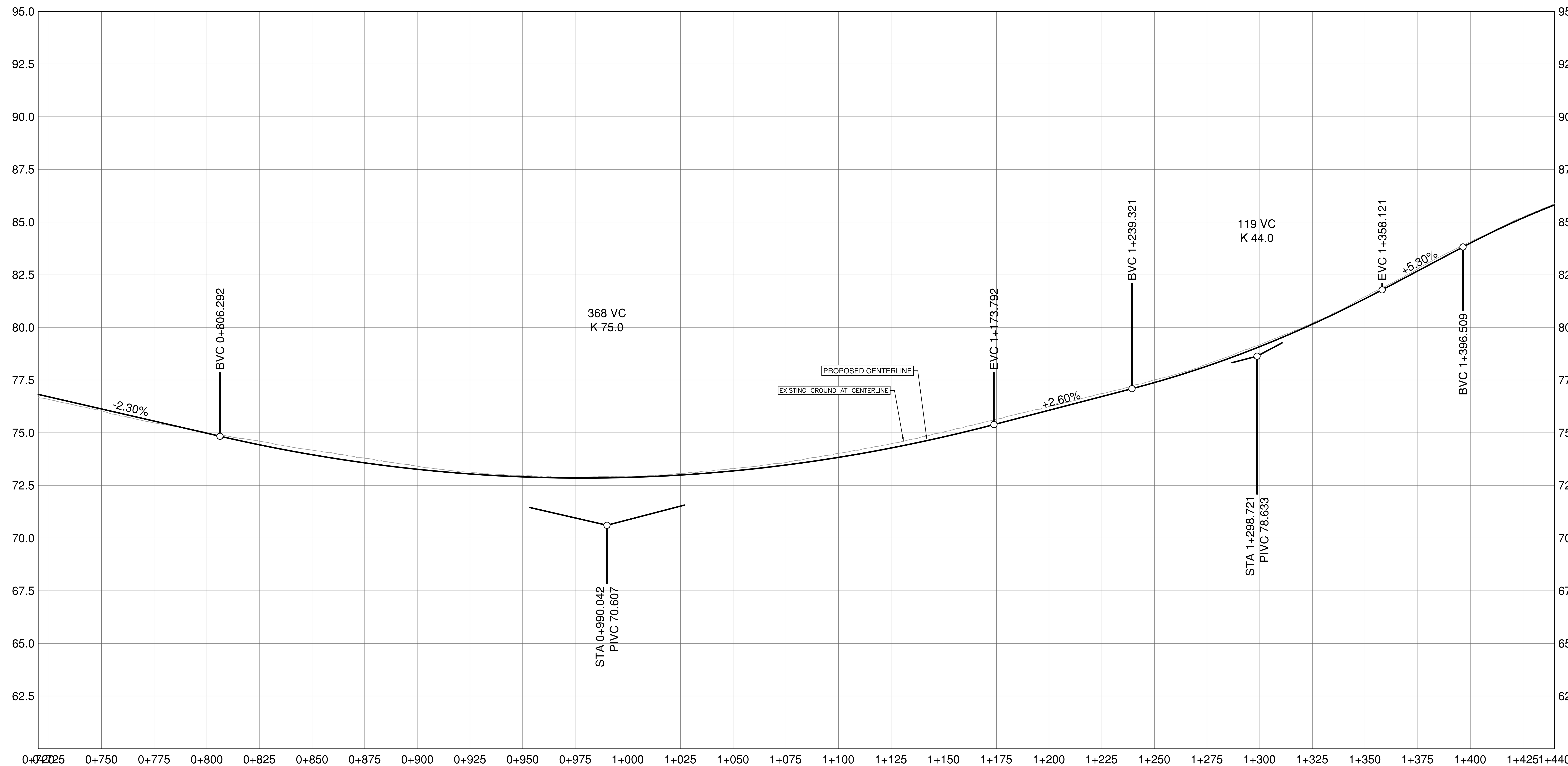

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REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

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HIGHWAY ENGINEERING AND GEOMATICS

SENIOR DESIGNER
DATE 2017-11-26

DESIGNED	BK	DATE	2017-11-26
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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

202

CHANCELLOR BOULEVARD
PROFILE

STA. 0+720.000 TO 1+440.000

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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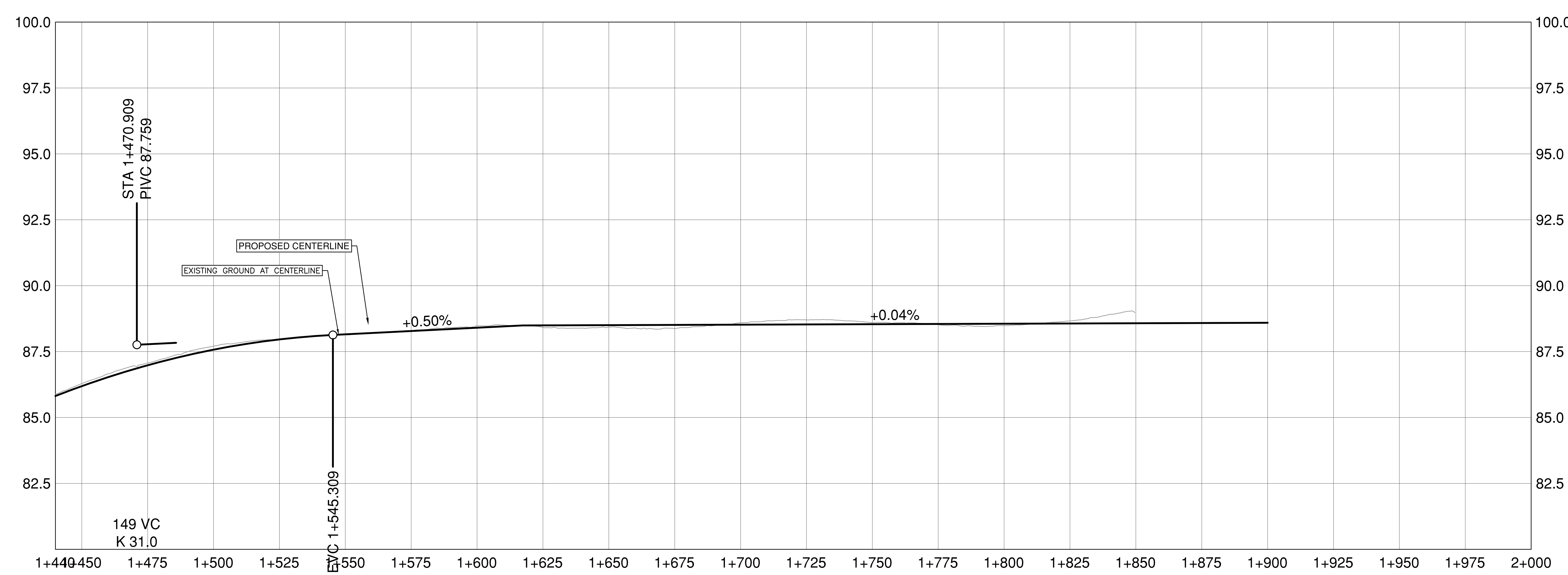

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CAD FILENAME C0-200

PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

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HIGHWAY ENGINEERING AND GEOMATICS

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QUALITY ASSURANCE CP DATE 2017-11-26
DRAWN BK DATE 2017-11-26

203

CHANCELLOR BOULEVARD PROFILE

STA. 1+440.000 TO 2+000.000

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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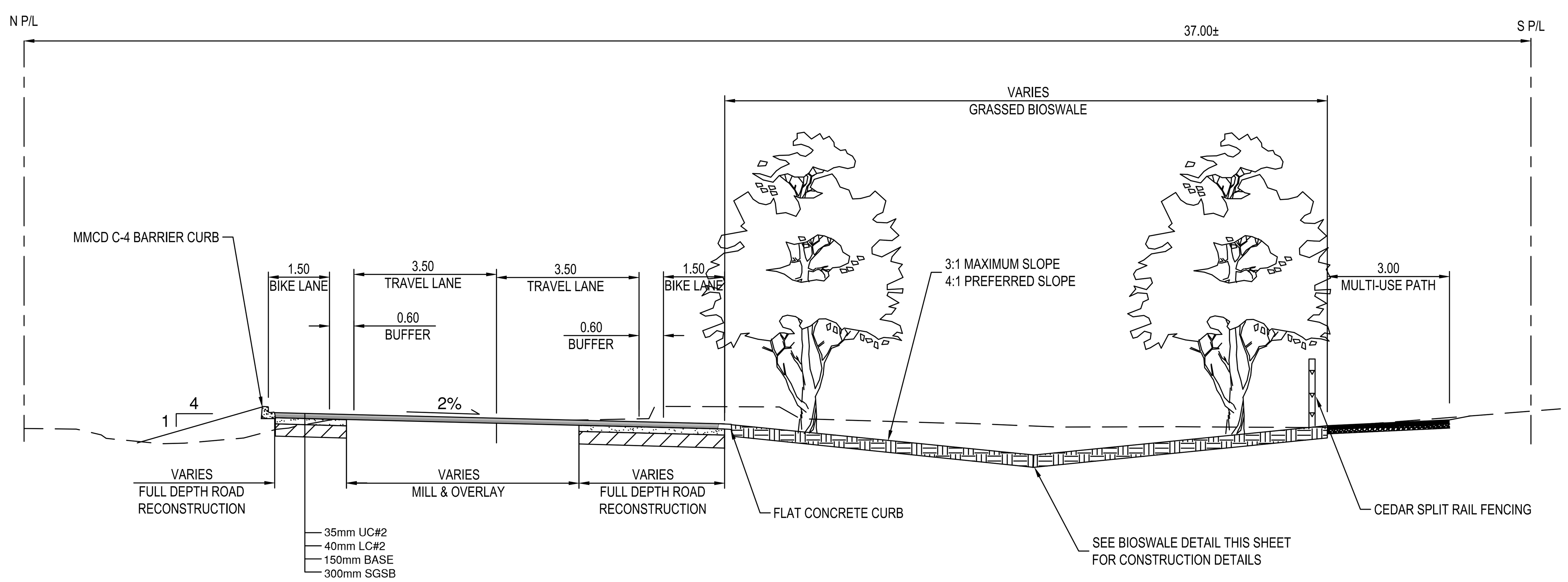
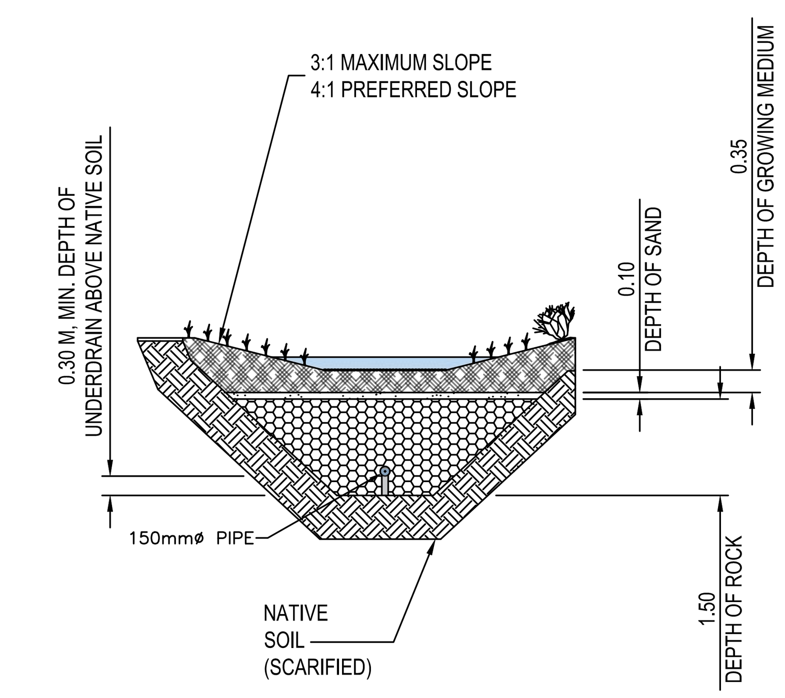


TYPICAL SECTION STN 0+480 TO STN 1+440

SCALE 1:100



BIOSWALE DETAIL

SCALE 1:100

SCALE 0 1 1:100 5m

CAD FILENAME C0-300
PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

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DATE 2017-11-26

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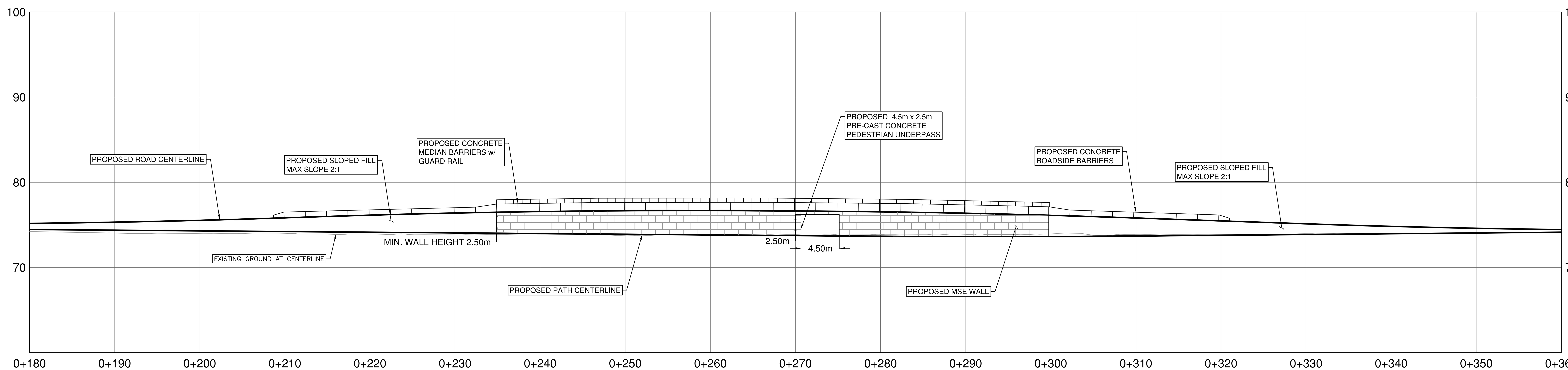
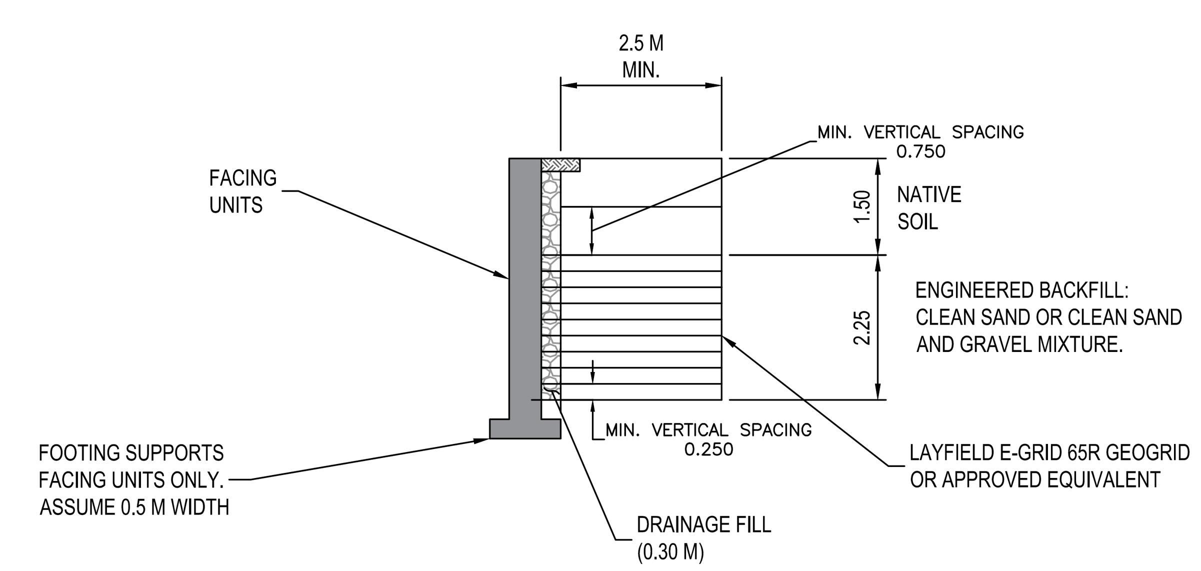
QUALITY ASSURANCE CP DATE 2017-11-26
DRAWN KO DATE 2017-11-26

301

CHANCELLOR BOULEVARD
DETAILS - CROSS-SECTIONS

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-300	A





PROPERTIES:
1. LESS THAN 12% PASSING AND 0.075 MM AND 100% PASSING 150MM
2. FRICTION ANGLE GREATER THAN 35° UNLESS TESTED OTHERWISE
3. PL LESS THAN 6
4. WATER CONTENT AT TIME OF COMPACTION AT OR BELOW 2% DRY OF OPTIMUM
5. COMPACTION: 95% OF STANDARD PROCTOR

MSE RETAINING WALL DETAIL

SCALE 1:100

SCALE 0 2 1:250 12m

CAD FILENAME C0-300
PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

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SOUTH COAST REGION
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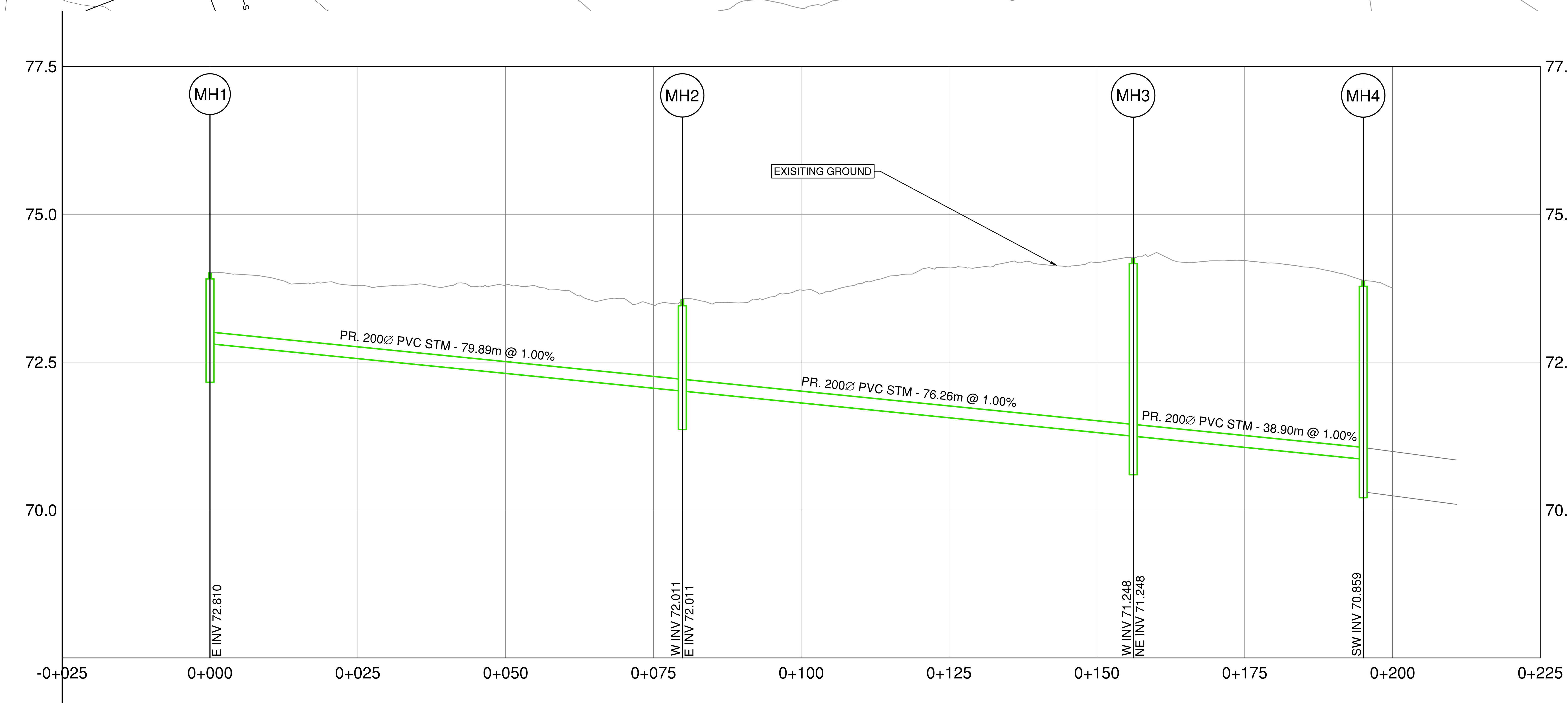
302
CHANCELLOR BOULEVARD
DETAILS - WALL GENERAL ARRANGEMENT

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-300	A



SCALE	0 5 H 1:500 25m / 0 0.5 V 1:50 2.5m	CAD FILENAME C0-600 / PLOT DATE 4/10/2018	
REV	DATE	REVISIONS	NAME
A			

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SOUTH COAST REGION
HIGHWAY ENGINEERING AND GEOMATICS

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DESIGNED	BK	DATE	2017-11-26
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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

601
CHANCELLOR BOULEVARD
CORRIDOR REDESGN
STORM PLAN & PROFILE

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-600 - 601	A

SCALE	0 5 H 1:500 25m / 0 0.5 V 1:50 2.5m	CAD FILENAME C0-600	PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
SOUTH COAST REGION
HIGHWAY ENGINEERING AND GEOMATICS

SENIOR DESIGNER
DATE 2017-11-26

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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

602
CHANCELLOR BOULEVARD CORRIDOR REDESGN STORM PLAN & PROFILE

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-600 - 602	A

SCALE	0 5 H 1:500 25m / 0 0.5 V 1:50 2.5m	CAD FILENAME C0-600	PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
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HIGHWAY ENGINEERING AND GEOMATICS

SENIOR DESIGNER

DATE 2017-11-26

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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

603
CHANCELLOR BOULEVARD CORRIDOR REDESGN STORM PLAN & PROFILE

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-600 - 603	A

SCALE 0 5 H 1:500 25m / 0 0.5 V 1:50 2.5m

CAD FILENAME C0-600

PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

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HIGHWAY ENGINEERING AND GEOMATICS

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DATE 2017-11-26

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QUALITY ASSURANCE	CP	DATE	2017-11-26
DRAWN	BK	DATE	2017-11-26

604
CHANCELLOR BOULEVARD
CORRIDOR REDESGN
STORM PLAN & PROFILE

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-600 - 604	A

SCALE	0 1 1:100 5m	CAD FILENAME C0-S100
		PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

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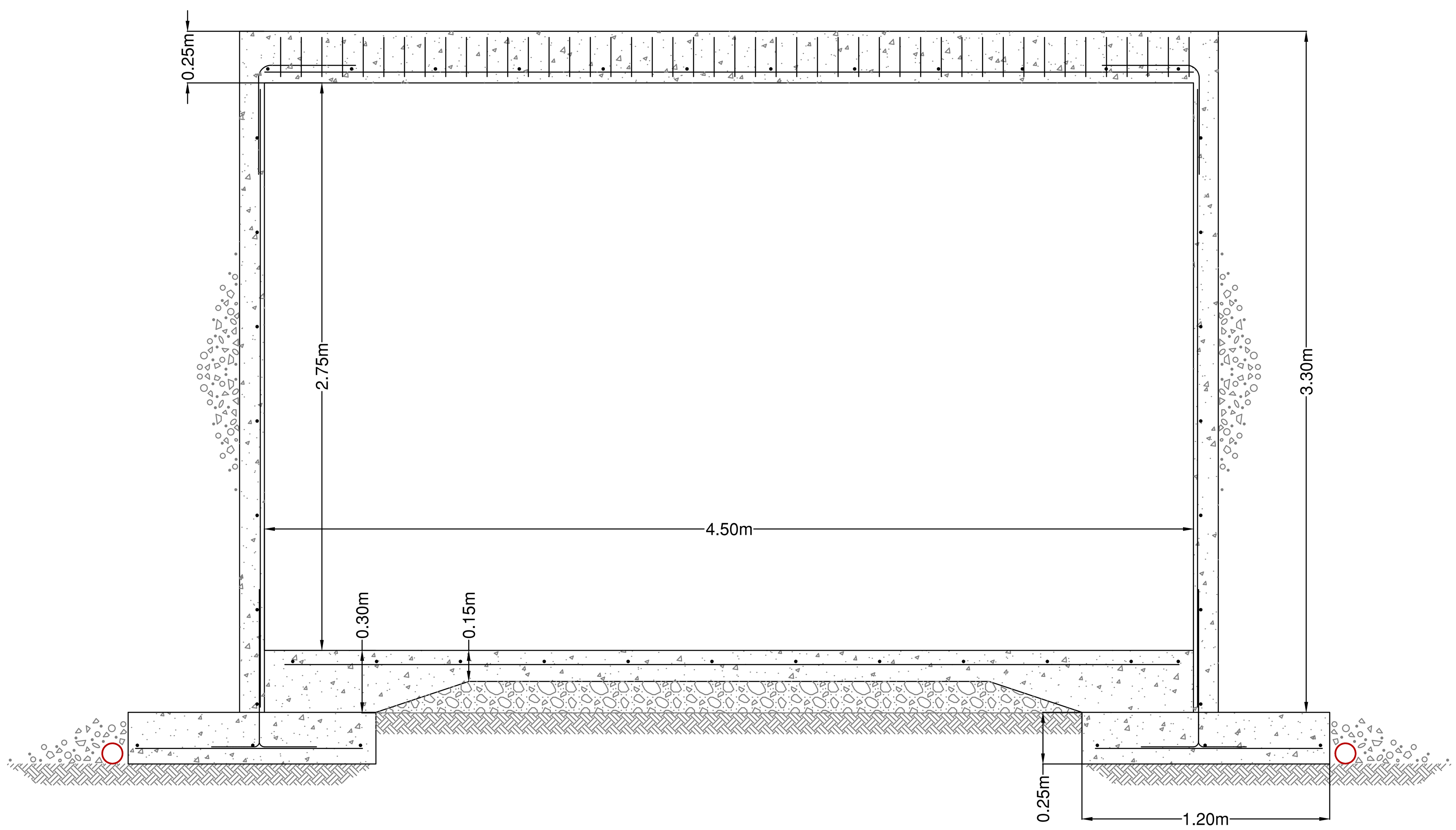
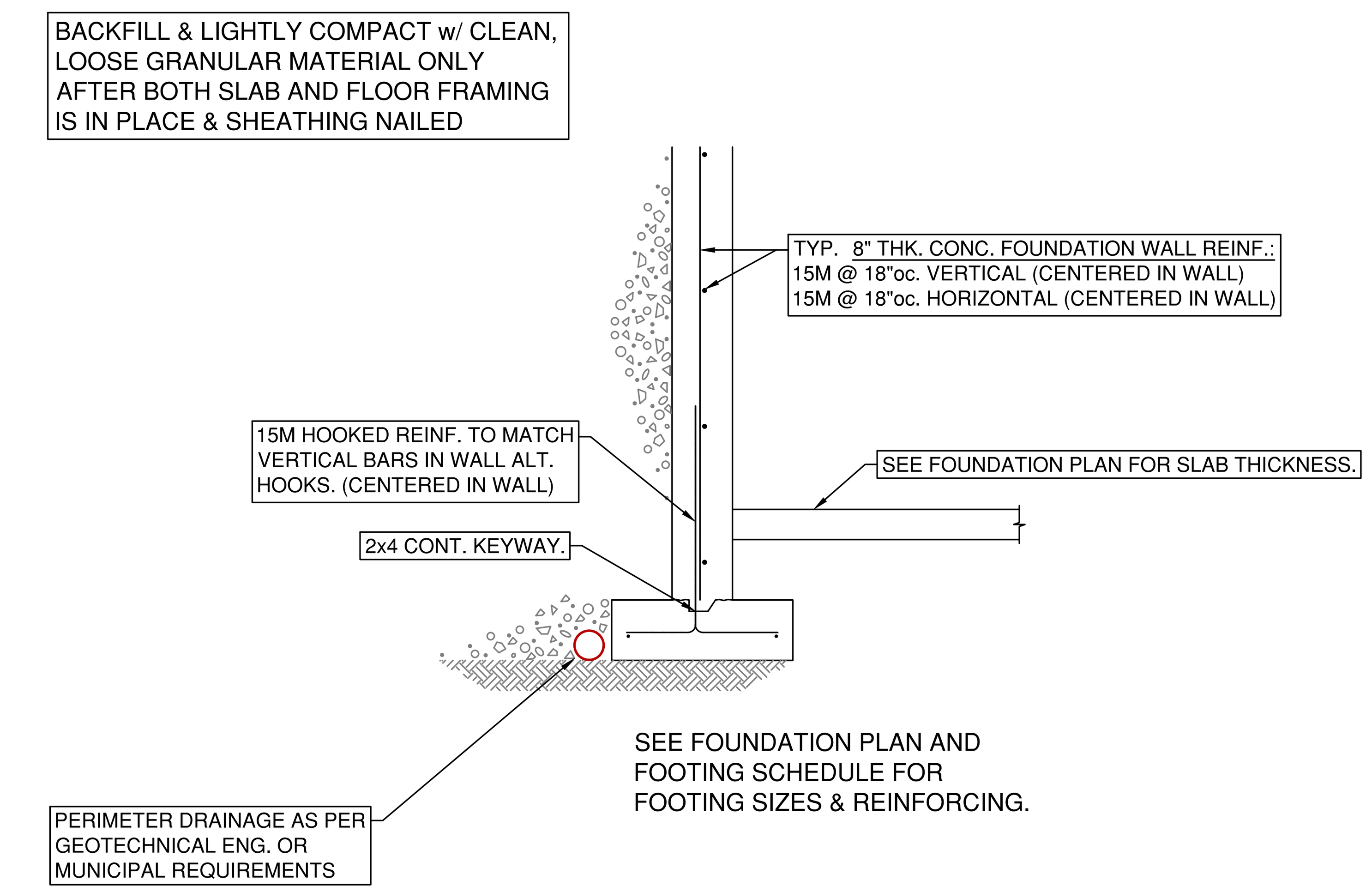
S-101
CHANCELLOR BOULEVARD CORRIDOR REDESGN PEDESTRIAN UNDERPASS PLAN

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-S100 - S-101	A



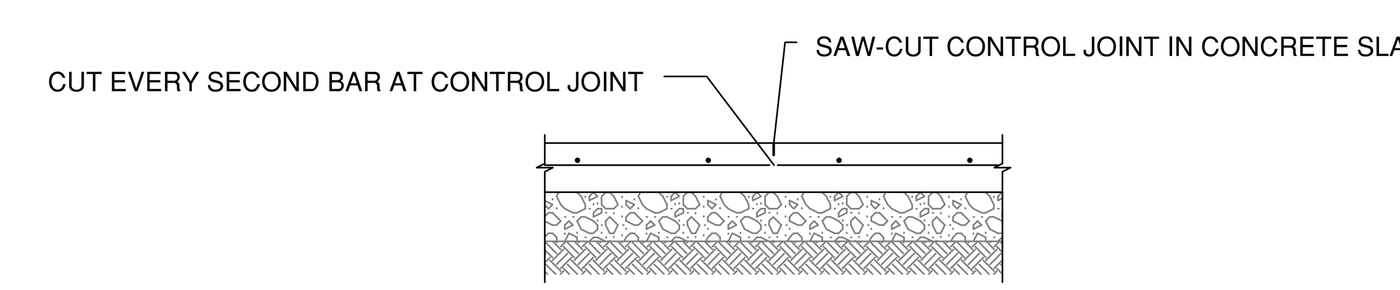
CAST-IN-PLACE PEDESTRIAN UNDERPASS TYPICAL SECTION

SCALE 1:20



TYPICAL WALL DETAIL

SCALE 1:20



TYPICAL SLAB ON GRADE CRACK CONTROL JOINT

SCALE 1:20

SCALE

CAD FILENAME C0-S100

PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

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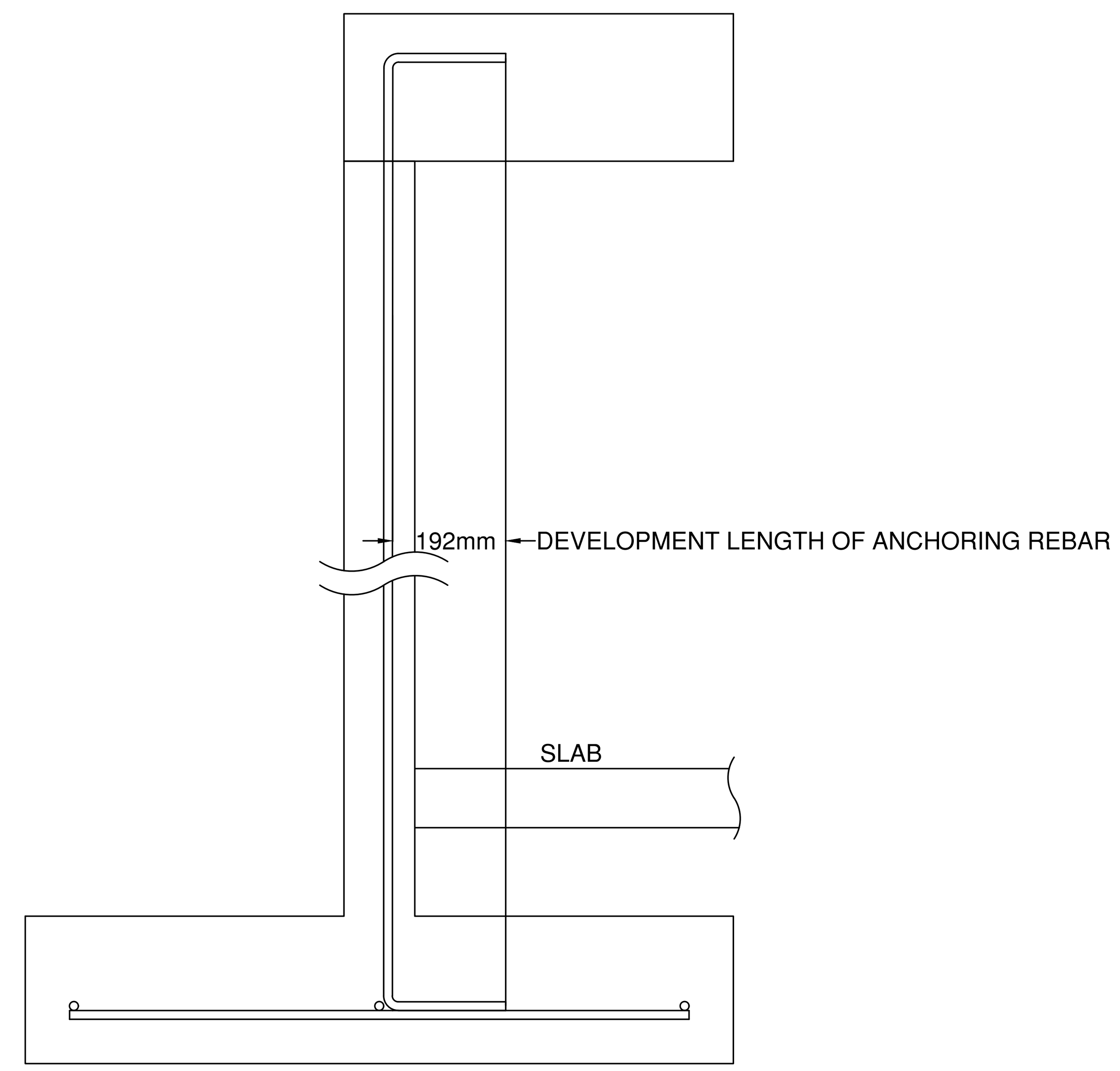
DRAWN	BK	DATE	2017-11-26

S-102

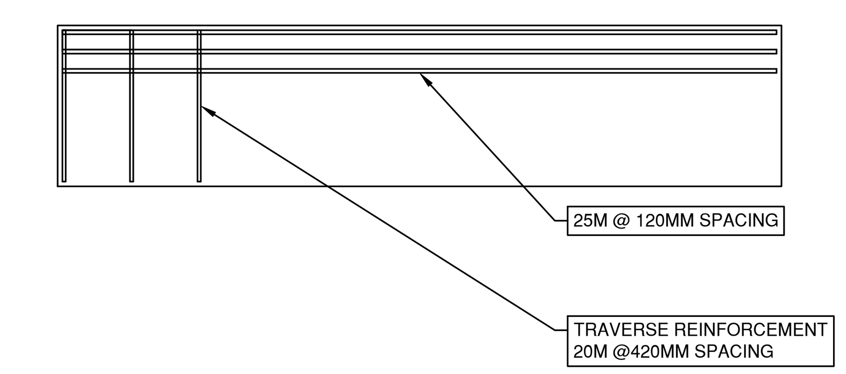
CHANCELLOR BOULEVARD
CORRIDOR REDESGN
PEDESTRIAN UNDERPASS
TYPICAL DETAILS

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-S100 - S-102	A



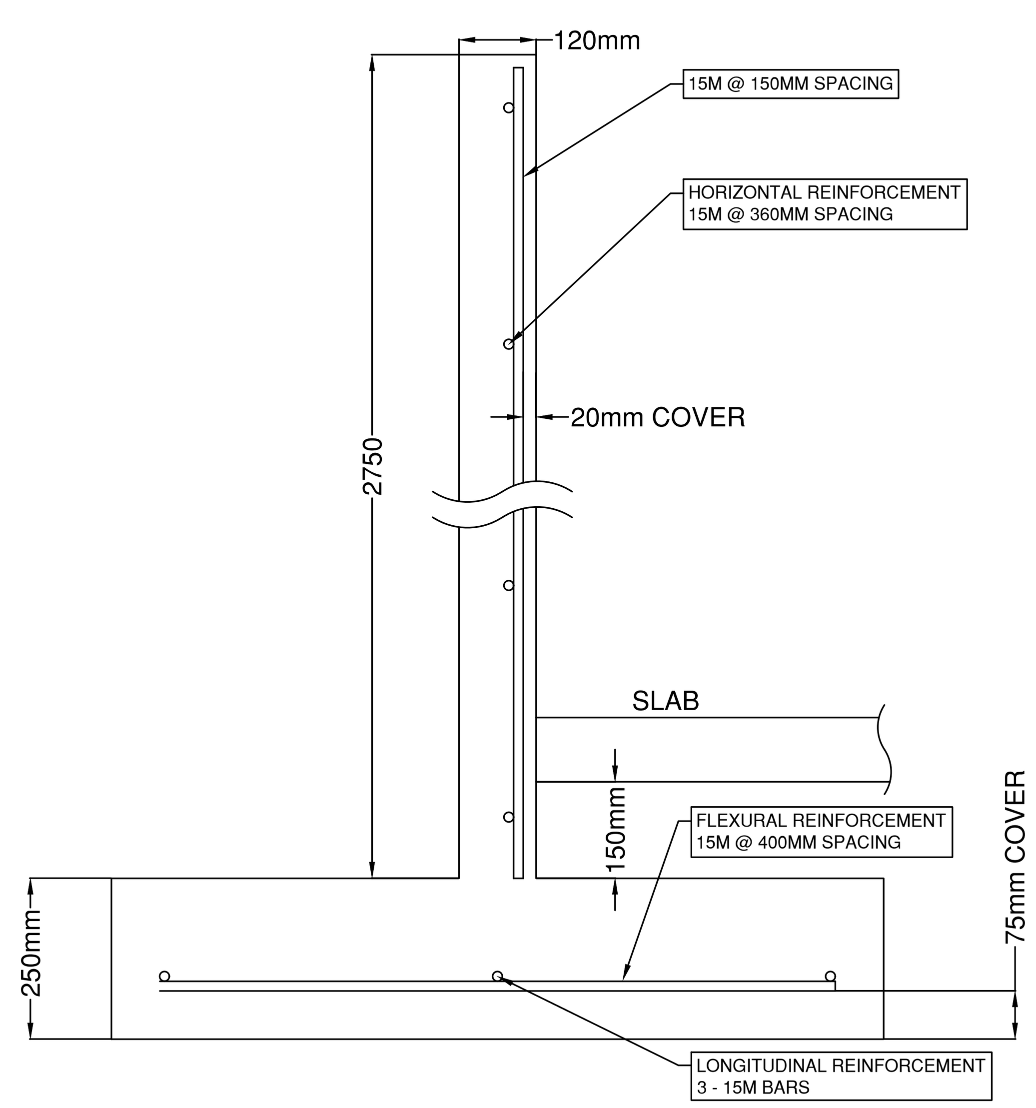
WALL DEVELOPMENT LENGTH DETAIL

SCALE 1:10



SLAB REINFORCEMENT DETAIL

SCALE 1:10



WALL REINFORCEMENT DETAIL

SCALE 1:10

SCALE

CAD FILENAME C0-S100

PLOT DATE 4/10/2018

REV	DATE	REVISIONS	NAME
A			

BRITISH COLUMBIA

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S-103
CHANCELLOR BOULEVARD
CORRIDOR REDESGN
PEDESTRIAN UNDERPASS
REINFORCEMENT DETAILS

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
N/A	N/A	1	C0-S100 - S-103	A